Lower Little Salt Creek Watershed Basin Evaluations

Urban Planning Zones N-1, N-2, N-3, N-4, and N-5

PURPOSE

The Lincoln Stormwater Basin Planning Project is being undertaken by the City of Lincoln and the Lower Platte South Natural Resources District (LPSNRD) to provide stormwater master planning for the entire city over a period of years. This project is targeted at continuing to implement the recommendations of the November 1994 Mayor's Stormwater Task Force Report. The report recommended comprehensive planning for stormwater management, using a basin-wide approach driven by local needs, and a collaborative effort among existing agencies to meet those needs. Proactive planning, rather than reactive planning, allows consideration of options that may no longer be feasible after development occurs.

This interim report is for the Lower Little Salt Creek (LLSC) watershed known as Urban Planning Zones (UPZ) N-1, N-2, N-3, N-4, and N-5 in the Lincoln\Lancaster County Comprehensive Plan (LLCCP). UPZs N-2, N-3, N-4, and N-5 are watersheds that collect into ephemeral streams that discharge to Little Salt Creek and UPZ N-1 is a handful of subwatersheds that drain directly into Salt Creek (refer to Figure I-1 Area Map).

These UPZs were projected by the LLCCP for urbanized development in the foreseeable future. Development in the upper portions of the Little Salt Creek watershed is not currently forecasted.

Originally, the City of Lincoln intended that this planning effort would result in a Stormwater Master Plan for UPZs N-1 through N-5. Environmental issues regarding the Salt Creek Tiger Beetle resulted in suspension of stormwater master plan efforts. Stormwater hydrology and hydraulic modeling for UPZs N-1 through N-5 was nearly completed when the Salt Creek Tiger Beetle issues arose. The hydrologic and hydraulic analyses of those UPZs were completed for existing and LLCCP-projected conditions and summarized in this Interim Report.

To facilitate the hydrologic and hydraulic modeling of the UPZs and the adjacent lower portion of Little Salt Creek, the upper portion of Little Salt Creek watershed was included as a singular large drainage area in the hydrologic model. UPZs N-1 through N-5 were each segregated into multiple drainage subbasins for more detailed analysis.

UPZ N-1 comprises a half-dozen drainageways that discharge directly into Salt Creek. It is generally located along either side of Interstate 80 from the Highway 77 (56th Street) interchange on the west, and to the Salt Creek Bridge near 84th Street on the east. It contains the City of Lincoln Bluff Road Landfill, the city's sludge injection site, the Abbot Sports Complex, and industrial/commercial development along Highway 77 and along Arbor Road.

UPZ N-2 is a watershed generally bounded by North 27th Street to the west, North 56th Street to the east, Waverly Road to the north, and Salt Creek to the south. It contains the Arbor Lake wetlands, owned by the City of Lincoln and managed by the Nebraska Game and Parks Commission, predominately agricultural land use with farmsteads, and a handful of acreages located in the extreme upper end of the watershed.

UPZ N-3 is a watershed generally bounded by North 27th Street to the west, North 56th Street to the east, Bluff Road to the south, and extending just beyond Raymond Road to the north. It contains predominately agricultural land use with farmsteads, and numerous acreages adjacent to the county road system.

UPZ N-4 is generally bounded by Northwest 12th Street to the west, North 27th Street to the east, Bluff Road to the north, and Alvo Road to the south. It contains predominately agricultural land use with farmsteads. Acreages are scattered throughout the watershed, and two developments located in the southwest corner of the watershed are in the early planning stages.

UPZ N-5 is bounded on the west by Northwest 12th Street, North 27th Street to the east, by Mill Road to the north, and by Bluff Road to the south. It contains predominately agricultural land use with farmsteads and acreages scattered throughout the watershed.

The purpose of this report is to present hydrologic and hydraulic characteristics of the watershed for existing and projected land use conditions, and to identify current and potential future stormwater issues.

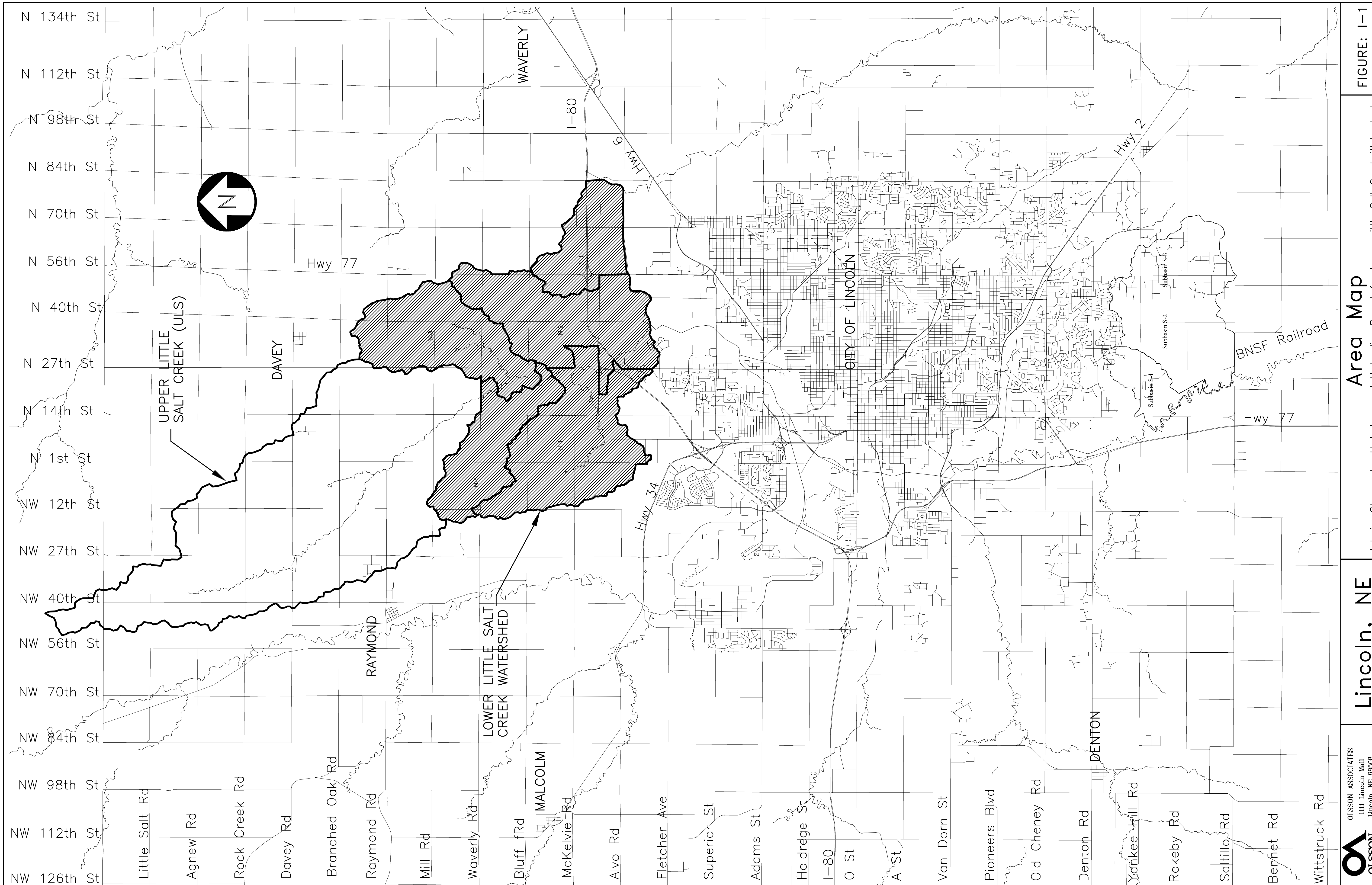
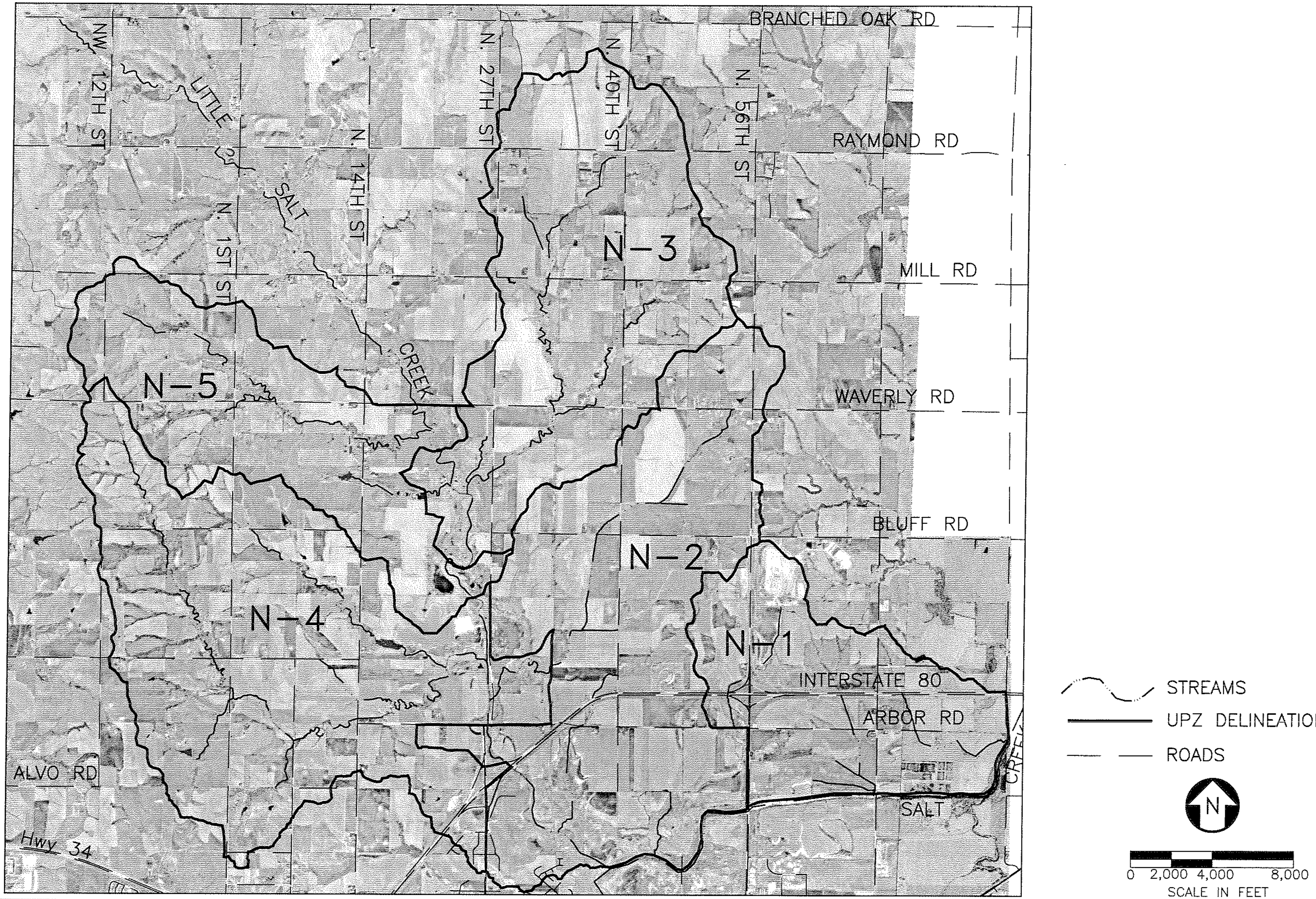


FIGURE: I-1
Area Map
Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed
Lincoln, NE
OLSSON ASSOCIATES
1111 Lincoln Mall
Lincoln, NE 68508
1-402-474-6311
N 134th St
N 112th St
N 98th St
N 84th St
N 70th St
N 56th St
N 40th St
N 27th St
N 14th St
N 1st St
NW 12th St
NW 27th St
NW 40th St
NW 56th St
NW 70th St
NW 84th St
NW 98th St
NW 112th St
NW 126th St
Little Salt Rd
Agnew Rd
Rock Creek Rd
Davey Rd
Branched Oak Rd
Raymond Rd
Mill Rd
Waverly Rd
Bluff fRd
McKelvie Rd
Alvo Rd
Fletcher Ave
Superior St
Adams St
Holdrege St
I-80
O St
A St
Van Dorn St
Pioneers Blvd
Old Cheney Rd
Denton Rd
Yankee Hill Rd
Rokeby Rd
Saltillo Rd
Bennet Rd
Wittstruck Rd
WAVERLY
DAVEY
RAYMOND
MALCOLM
DENTON
CITY OF LINCOLN
UPPER LITTLE SALT CREEK (ULS)
LOWER LITTLE SALT CREEK WATERSHED
Hwy 77
Hwy 6
Hwy 2
Hwy 34
I-80
BNSF Railroad
Subbasin S-1
Subbasin S-2
Subbasin S-3
N



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1111 Lincoln Mall
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Lincoln, Nebraska

Watershed Boundary Map

Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed

FIGURE: I-2

GOALS AND OBJECTIVES

Successful master planning for stormwater management involves identifying issues, establishing goals and preparing a plan to meet those goals. Public involvement in each of these areas is the key to developing support. An open house was held to gather public comment on existing and projected stormwater issues and goals. The Salt Creek Tiger Beetle is included on the State of Nebraska list of threatened and endangered species and is a candidate for the federal list. Due to the uncertainty of the possible endangerment of the Salt Creek Tiger Beetle, future development in the watershed may be affected. The City of Lincoln and the LPSNRD have decided to suspend stormwater master planning in the LLSC Watershed until reliable land use projections can be determined for areas adjacent to, or areas that may potentially impact Salt Creek Tiger Beetle habitat in Little Salt Creek.

Public Involvement Process

An open house was held on March 29, 2001, from 5 p.m. to 7 p.m. at the LPSNRD offices. City, NRD and consultant staff were on-hand to answer questions posed by attendees. Concerns generally regarded loss of floodplain storage, preservation of saline wetlands, presence of endangered and threatened species in the watershed, stream bed degradation, quality of stormwater runoff from developments, preservation of habitat along streams, and changes from agricultural to urban land uses. Opposing view points about development in the floodplain were voiced. Some were in favor of preserving the entire floodplain with buffers outside the floodplain limits, while others favored allowing development in the floodplain if buildings were raised 1-ft above the base (1% chance) flood level. A meeting was also held with local and state agency representatives to provide information on public involvement and technical processes, and to discuss preliminary issues and goals. Copies of the sign-in sheet and written comments are provided in Appendix A. The public involvement process will continue to help refine, clarify, and resolve public and governmental issues.

Goal

The goal of this planning project is to create a master plan for stormwater management policies, procedures, and facilities. The master plan will anticipate and outline strategic tactics to manage the effects of development in the watershed. The master plan will also serve to proactively coordinate the efforts of the various entities that may be responsible for creating or maintaining infrastructure, buildings, or property in the watershed (i.e., State Department of Roads, City of Lincoln/Lancaster County Roads Department, private developers, landowners, business owners, etc.), as well as managing habitat of state or federally listed threatened or endangered species. The master plan is intended to be up-to-date, cost-conscious, effective, practical and meet the unique current and foreseeable community needs of Lincoln/Lancaster County, while meeting applicable regulatory requirements.

Key Issues

Following are some of the key issues that need to be addressed for the watershed in the Stormwater Basin Planning Project.

- Stream stability, and management of increased volume and rates of runoff due to urbanization and development in the watershed
- Increased flood hazard and risk due to development in the floodplain
- Evaluation of runoff quantity and quality on area wetlands
- Road crossings, existing development in the floodplain, and private property rights
- Funding and coordination with floodplain regulation review and implementation
- Evaluating and improving upland land uses and water quality during and after development
- Protection of saline wetlands and the effect of runoff and development on threatened and endangered species in the saline wetlands (Salt Creek Tiger Beetle and Saltwort)
- The presence of active and closed landfills

Evaluation

Information on existing and projected land use, soil type, and other hydrologic characteristics for the watershed is presented below. Results from hydrologic and hydraulic models developed and operated for existing and projected land use conditions are presented. Evaluation of the results indicate peak rates of runoff increase from subbasins projected to urbanize, but other factors may have a more significant impact on stormwater management. The master planning process will help determine what actions should be taken to mitigate stormwater management issues for existing and projected conditions.

LAND USE

Land use changes associated with urbanization can potentially have a significant impact on the hydrologic response of a watershed to rainfall events. Stormwater master plans evaluate existing and projected hydrologic conditions and, based on established goals, identify actions to mitigate undesirable conditions and preserve desirable conditions.

As urbanization occurs, runoff volume and rates typically increase due to increased impervious areas, and more efficient conveyance through paved streets and storm drain systems. Unless anticipated during the design process, increased runoff volume and rates may cause new problems or exacerbate existing problems in the storm drain system, such as increased flooding, more frequent flooding, stream degradation, or bridge replacement needs.

Table I-1 provides a summary of 2001 land uses in the LLSC watershed based on information obtained from aerial photography, watershed tours, current land use maps, and built-out conditions based on the LLCCP. Table I-2 provides the percent developed for each Urban Planning Zone for existing and LLCCP conditions.

Existing Land Use Conditions

Figure I-3 shows the spatial distribution of existing land use in the study area. The study area is mostly agricultural with scattered acreages and farmsteads. Development is underway northwest of the North 27th Street interchange on Interstate 80.

Urban residential lots average 8,000 to 10,000 sf (1/5-acre to 1/4-acre). Typically between 40% and 50% is impervious pavement or roof tops. Soil characteristics are less of a factor than the impervious percentage on stormwater management issues. Runoff is collected in street gutters, and flows through a storm drain system to discharge into a tributary channel.

Rural residential lots average three acres and less than 12% of the area is typically impervious pavement or roof top. The remainder of lot area is vegetated and landscaped. Runoff typically flows overland, and through vegetative swales, before entering the storm drain system. The vegetation and soil characteristics are a greater factor on stormwater management issues than the relatively small percent of impervious area. Consequently, the runoff potential for a subbasin with rural residential land use can be less than for cultivated agricultural land uses.

Commercial development is characterized by large expanses of impervious area that are directly connected to the storm drain system. More precipitation becomes runoff and, because the storm drain system efficiently transports water, the runoff peak arrives at the channel sooner than that from undeveloped land.

Agricultural land use has a very low impervious component, typically less than 2%. Residual cover, tillage practices, and soil type are equally important factors for stormwater management.

Natural and environmental land uses, parks, and open spaces are characterized by large expanses of pervious areas that are not connected to a storm drain system. Issues due to runoff from adjacent property are typical stormwater management concerns.

The channels in the upper portions of the LLSC watershed and LLSC mainstem exhibit little degradation. The channels showed mild to severe incision in the reaches of Little Salt Creek below Bluff Road extended, and in the tributary channel with confluences in that reach of the Little Salt Creek channel. Natural riparian vegetation still exists in some areas, and in other areas agricultural activities take place right up to the edge of the drainageway channel. The natural drainageways have been respected generally, with little straightening having occurred. Saline wetlands are found along this segment of the channel. Wright Water Engineers prepared a report entitled "Constraints of Habitat and Channel Stability on the Development of Drainage Improvement Alternatives for the S-1 to S-3 and N-1 to N-5 Urban Planning Zones". The report is an evaluation of channel stability written by Dr. Edwin Herricks, P.E., Professor of Environmental Biology, University of Illinois at Urbana-Champaign. The complete text of the report is available in Appendix B.

Table I-1
Summary of 2001 Land Use in the Lower Little Salt Creek Watershed Study Area (percent)

Condition	Urban Residential	Rural Residential	Commercial and Industrial	Agricultural	Grassland	Water Bodies	Total
Existing	2.4	0.6	3.8	84.8	3.8	4.6	100.0
LLCCP	5.8	0.6	7.8	76.5	4.7	4.6	100.0

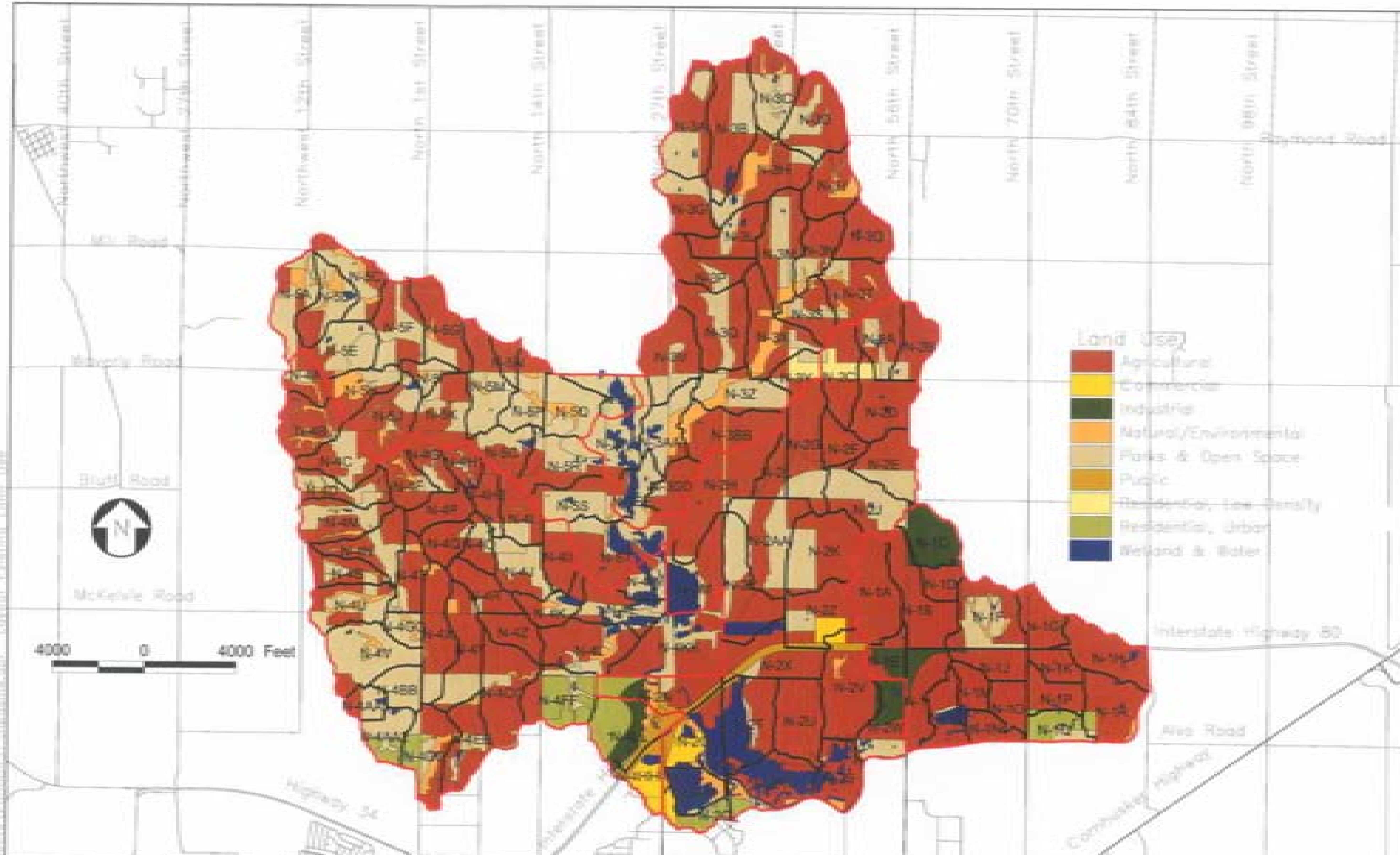
Projected Land Use Conditions

The Lincoln Lancaster County Comprehensive Plan (LLCCP) projects land uses for the next 25-year plan period. Projections of land use from the LLCCP through the year 2025 were used to determine future hydrologic conditions in the watershed. Figure I-4 shows the spatial distribution of projected future land use in the LLSC watershed. Typical components identified in stormwater master plans, such as dams and road crossings, have a design life in excess of 25 years and should be designed so as to not become prematurely obsolete. Component performance should be evaluated with built-out peak flow rate values for cost analysis. Built-out conditions are those expected to exist when all of the properties within the watershed have attained their "highest and best use." This is influenced by future revisions to the LLCCP, availability of sewer and water utilities, zoning regulations, restrictive (protective) covenants, or by other legally binding documents.

No immediate growth is projected in the Little Salt Creek watershed (UPZs N-2 through N-5, except the part of N-2 that discharges to Little Salt Creek downstream of Arbor Road). UPZ N-1, which is generally south of Interstate 80 between North 56th Street and North 84th Street, is expected to continue developing. Current concerns with the effect of urbanization on the Salt Creek Tiger Beetle habitat, adjacent to Salt Creek and Little Salt Creek, have resulted in a call for additional research into the Salt Creek Tiger Beetle. See the Salt Creek Tiger Beetle Cabinet Report for full definitions and detailed explanations at *www.lincoln.ci.lincoln.ne.us/city/plan/tig_bug.pdf.* No further development is projected to occur in the LLSC watershed until the impacts of development on the Salt Creek Tiger Beetle habitat are studied further. Stormwater master planning for UPZs N-1 through N-5 also will not proceed further until the Salt Creek Tiger Beetle studies have progressed.

Table I-2
Developed Area in the N-1, N-2, N-3, N-4, and N-5 Urban Planning Zones

Location	Area (sm)	Percent Developed Existing Conditions	Percent Developed LLCCP Conditions
Urban Planning Zone N-1	3.0	13.3	44.7
Urban Planning Zone N-2	6.2	10.2	24.3
Urban Planning Zone N-3	5.4	1.1	1.1
Urban Planning Zone N-4	6.8	9.1	9.3
Urban Planning Zone N-5	3.8	0.0	0.0
Upper Little Salt Creek	24.0	Outside limits of detailed study	



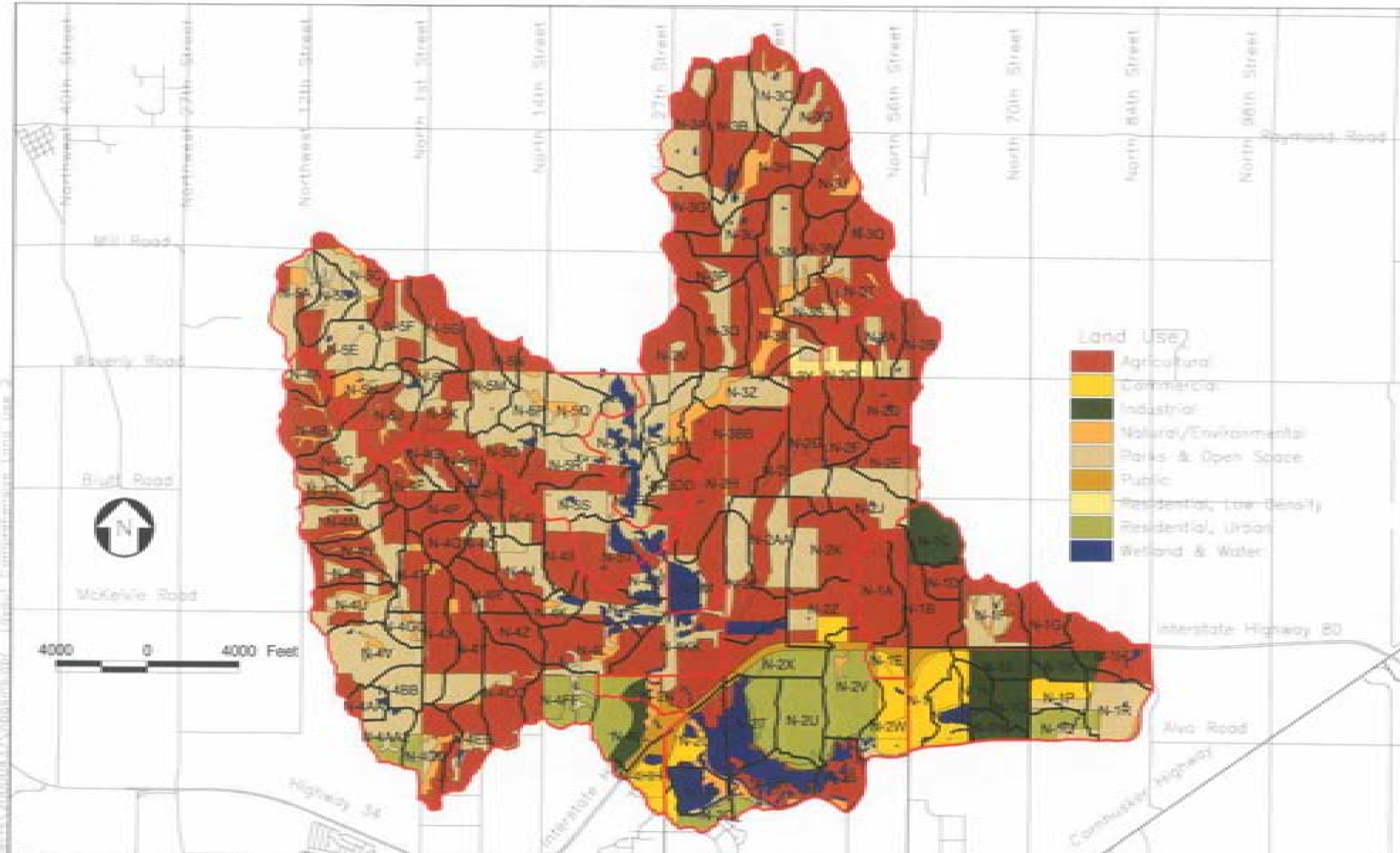
OLSSON ASSOCIATES

Lincoln, Nebraska

Existing Land Use Conditions

Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed

FIGURE: 1-3



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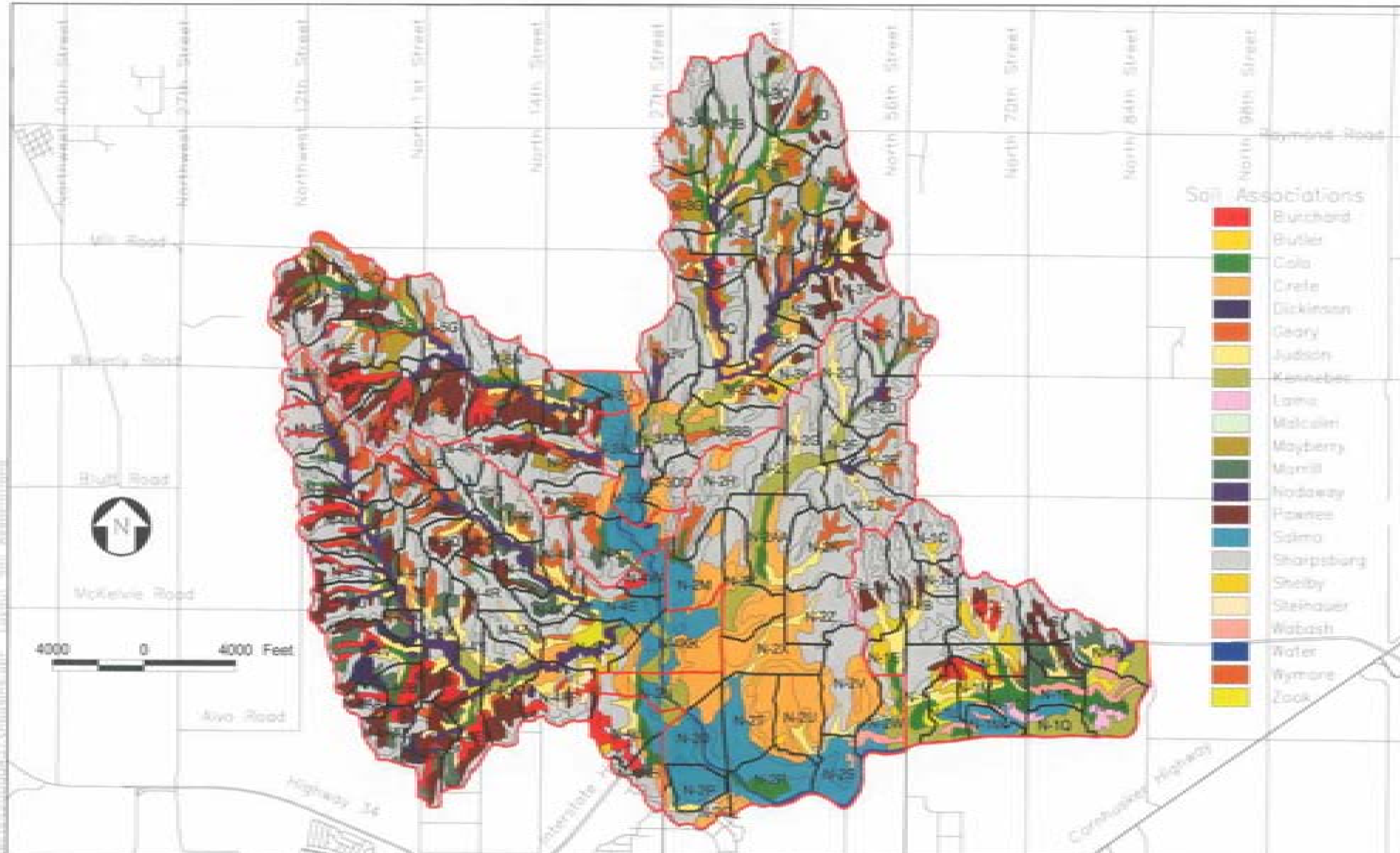
Projected Land Use Conditions

Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed

FIGURE: 1-4



Lincoln, Nebraska

Soil Associations

Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed

FIGURE: 1-5

SOILS

Soil type can have a profound effect on the runoff generated from precipitation. The amount of precipitation that infiltrates into the soil does not immediately become runoff. The predominant soil series found in the UPZ N-1, N-2, N-3, N-4, and N-5 watersheds are shown on Figure I-5 and listed in Table I-3 in descending order of approximate area. Approximately 11.8% belongs to the Wymore-Pawnee association, which erodes easily and consists of deep, nearly level to strongly sloping, moderately well drained, silty soils that formed in loess and loamy soils that formed in glacial till. This soil association is found on uplands and has a very slow infiltration rate (high runoff potential) when thoroughly wet. The Kennebec-Nodaway-Zook association consists of deep, nearly level and very gently sloping, moderately well drained to poorly drained, silty soils that formed in alluvium. This soil erodes easily, has a moderate to slow infiltration rate when thoroughly wet, is subject to flooding, and is found in floodplains. The Pawnee-Burchard association consists of deep, gently sloping to steep, moderately well drained and well drained, loamy and clayey soils that formed in glacial till. These soils erode easily, percolate slowly, have a slow infiltration rate (high runoff potential) when thoroughly wet, and are found on uplands.

Although outcrops of the Dakota Sandstone formation are shown to be present in the Bedrock Geology Map (Bedrock 1972) north of Waverly Road near 14th Street, no outcrops are indicated in the Lancaster County Soil Survey. Figure I-5 graphically displays the soil associations.

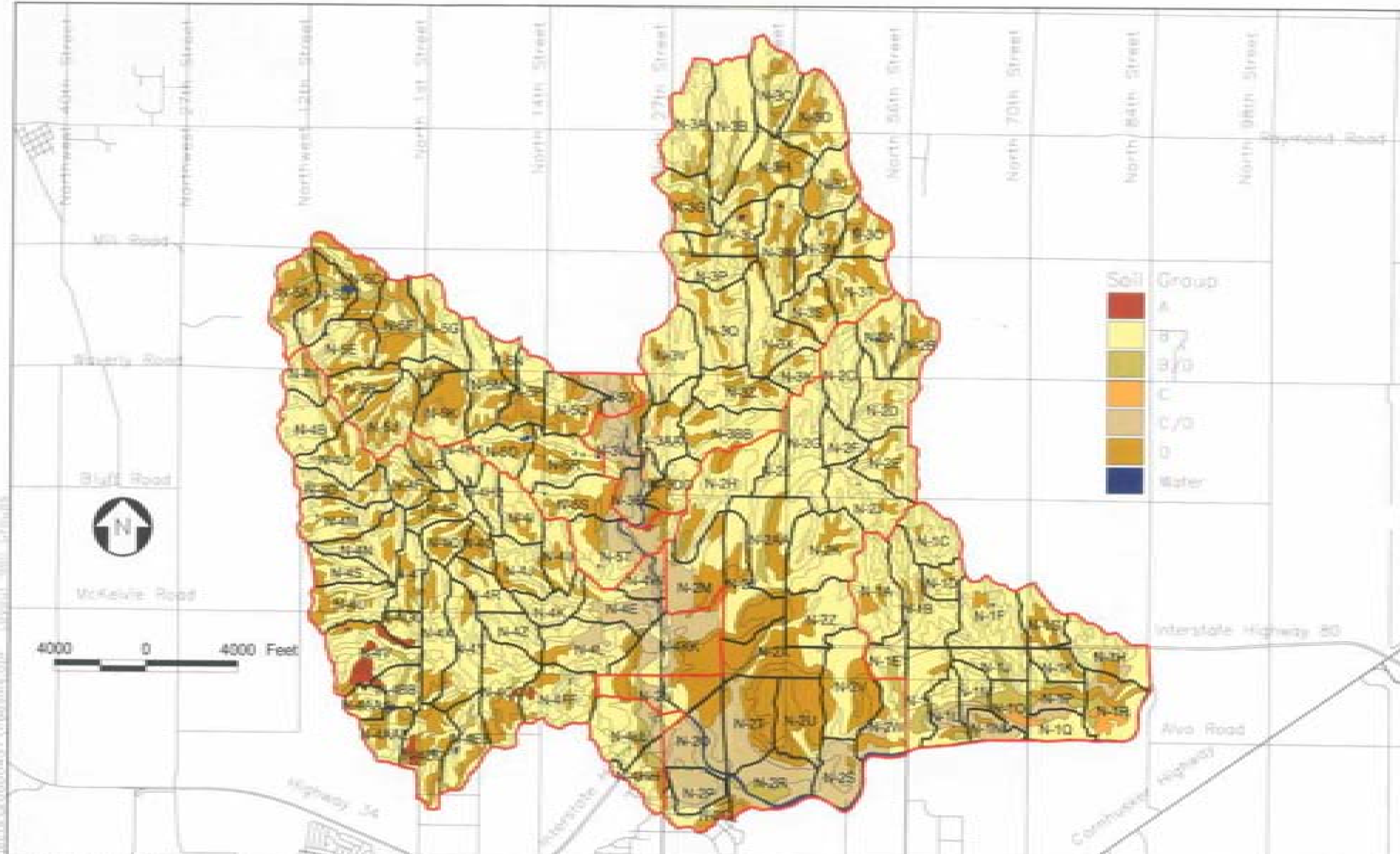
SALINE WETLANDS

Of particular interest in this investigation are the soils found along Little Salt Creek and Salt Creek. They are unique to Lancaster County and southern Saunders County. The Salmo Soil series is found in the floodplains of Little Salt Creek and Salt Creek. The locations of Salmo soil in the Little Salt Creek watershed is shown on Figure I-5. Salmo soils contain up to 0.31 percent soluble salts and have a salinity value of 4 to 16 millimhos per centimeter, which is a measure of the soluble salts in the soil at saturation. The other soils found in the watershed have a value less than two millimhos per centimeter. Saline soils are also frequently flooded and have a high water table. A hardpan layer is visible in the banks of Little Salt Creek at many locations. Saline wetlands can be found on much of the saline soils in Little Salt Creek (see Figure I-7). Most plants will not grow or may not thrive in these hostile conditions; however, a select group of plants do grow and can thrive in this unique habitat. A publication titled "Nebraska Wetland Resources" was issued in 1997 by the Nebraska Department of Environmental Quality (NDEQ). It is a summary of the joint efforts of NDEQ, Nebraska Game and Parks Commission, and the Nebraska Natural Resources Commission (since merged with the Department of Water Resources and renamed Nebraska Department of Natural Resources). It provides a description of three plants growing in the "Eastern Saline wetlands" that are found growing nowhere else; saltmarsh aster, saltwort, and Texas dropseed. These plants are considered rare in Nebraska. The summary also identifies the Salt Creek Tiger Beetle "a very rare and geographically restricted subspecies", and it is a candidate for the federal threatened or endangered species list. A listing of this species would provide protection of the beetle and its habitat if a proposed project requires a federal permit or is partially or fully funded by federal monies. It would not provide regulatory protection if a project is privately funded and does not require a federal permit.

In 2001, the Mayor established the Salt Creek Tiger Beetle Cabinet to study the situation and evaluate potential solutions that better meet the local needs. The cabinet includes experts in biology, entomology, ground and surface water, planners, and representatives of developer and environmental groups. Their recommendations were published in December 2001 and are available on the city web site at *www.ci.lincoln.ne.us/city/plan/tig_bug.pdf.* Concerns have been expressed by the development community, property owners and city and county departments. The cabinet report made short-term and long-term recommendations. Short-term recommendations include; the need for ongoing coordination with the city and other entities, determining immediate measures to enhance and preserve existing saline wetlands, removing saline wetland areas from Tier I and Tier II development zones of the Comprehensive Plan, prioritizing acquisition of land in the Salt Creek watershed, and authorizing or soliciting funds for additional research. Long-term recommendations include; developing a plan for the Salt Creek watershed, and a coordinated multi-agency approach for research, education, and preservation efforts.

Table I-3
Comparison of Soil Series Found in the Watershed (USDA, SCS Soil Survey of Lancaster County, NE)

Property		Soil Series						
		Sharpsburg	**Pawnee**	**Judson**	**Wymore**	**Crete**	**Morrill**	**Salmo**
Parent Material		Formed in loess	Formed in glacial till	Formed in non-calcareous colluvial silty sediment from uplands	Formed in loess	Formed in loess	Formed in till or outwash or retreating glaciers	Formed in silty alluvium
Drainage		Moderately well drained	Moderately well drained on uplands, slow permeability	Moderately well drained on colluvial foot slopes, moderate permeability	Moderately well drained on uplands, slow permeability	Moderately well drained on uplands and stream terraces	Deep well drained upland soils, moderate slow permeability	Deep, poorly drained on bottom lands, slow permeability
Surface Layer		Very dark brown friable silty clay loam	Very dark brown clay loam, very dark grayish brown, weak fine granular structure, slightly hard	Very dark brown silt loam; weak fine granular structure; slightly hard, friable: medium acid	Very dark brown silty clay loam, weak fine granular structure, hard	Black silt loam weak fine granular structure; slightly hard, friable; medium acid	Dark brown, friable clay loam	Black to very dark gray silty clay loam; weak medium subangular blocky structure; hard, friable; slight effervescence; 0.31% soluble salts, mildly alkaline
Subsoil	**Upper**	Dark brown, firm silty clay	Very dark grayish brown clay, moderate fine and medium subangular blocky structure	Dark brown silty clay loam; moderate medium prismatic structure; hard, firm; medium acid	Dark brown silty clay, moderate fine and medium subgranular blocky structure, hard	Very dark grayish brown silty clay; moderate medium prismatic structure; slightly hard, friable; medium acid	Dark reddish brown clay loam; weak fine angular structure; slightly hard, friable; medium acid	Very dark gray silty clay loam, weak medium granular structure, hard, friable; 0.16% soluble salts, mildly alkaline
	Middle	Brown firm silty clay	Dark grayish, moderate medium prismatic structure, very hard	Dark brown silty clay loam; weak medium prismatic structure; medium acid	Dark grayish brown silty clay, moderate medium prismatic structure, hard	Dark grayish brown silty clay; strong medium prismatic structure; very hard, very firm; neutral	reddish brown clay loam; moderate medium subangular; hard, firm; medium acid	Black silty clay loam; weak, medium subangular structure; hard, friable, slight effervescence; 0.16% soluble salts, mildly alkaline
	Lower	Yellowish brown, firm or friable silty clay loam	Olive brown clay, moderate medium prismatic structure, very hard	Brown silty clay loam; massive; slightly hard, friable; slightly acid	Olive brown silty clay loam, weak medium prismatic structure, hard	Grayish brown silty clay; weak coarse prismatic structure; slightly hard, friable; small lime concretions, mildly alkaline	brown clay loam, weak medium prismatic structure; slightly hard, friable; slightly acid	Very dark gray silty clay loam; few fine distinct dark yellow brown mottles; massive, hard, friable; strong effervescence; 0.18% soluble salts; mildly alkaline
Underlying Material		Light yellowish brown silty clay loam	Olive clay loam, weak coarse prismatic structure, slightly hard	Silty clay loam, dark grayish brown with yellow brown mottles	Olive gray silty clay loam, slightly hard	Brown clay loam	Brown to reddish brown clay loam	Dark grayish brown silt loam, generally calcareous



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Hydrologic Soil Groups

Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed

FIGURE: 1-6

HYDROLOGIC SOIL GROUPS

NRCS soil scientists have classified soils into four hydrologic soil groups according to their runoff potential. The manual for TR-20, "Urban Hydrology for Small Watersheds" provides the following definitions:

"Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B soils have moderate infiltration rates [and moderate runoff potential] when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C soils have low infiltration rates [and high runoff potential] when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission.

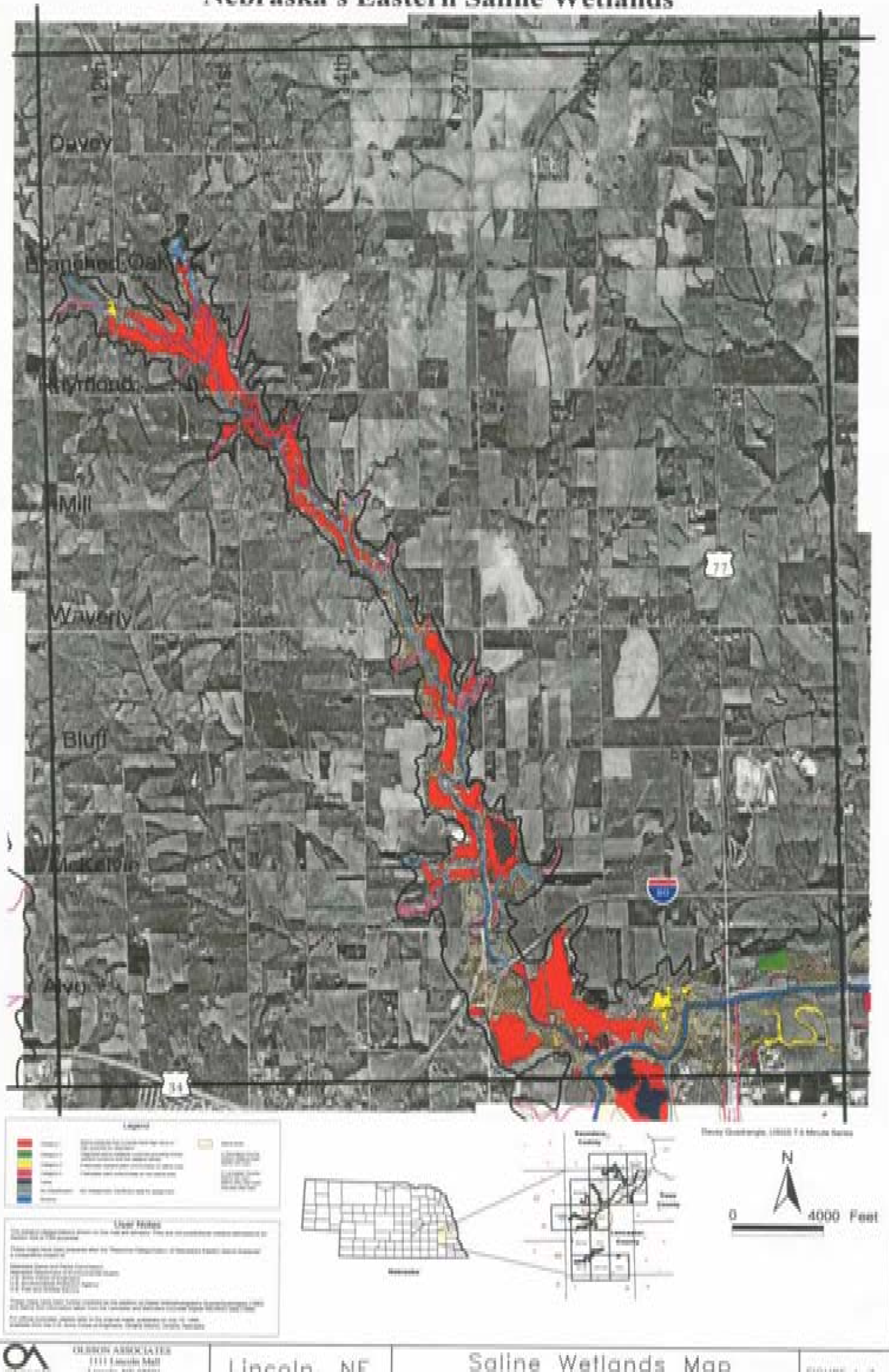
Group D soils have a high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission."

The Lancaster County Soil Survey indicates the presence of Group A soils in N-4 southwest of North 14th Street and McKelvie Road. Group B soils are the predominant type found in spots throughout the watershed in both uplands and along channels. Group C soils are located along Little Salt Creek, from the upper limit of the study area at Waverly Road, to the mouth of Little Salt Creek and along the Salt Creek overbanks in UPZ N-1. They consist entirely of saline soils with the exception of a very small amount of Zook soils. Group D soils are found in spots throughout the watershed, mostly in the uplands. Table I-4 provides a description of the soils found in the LLSC watershed, and an indication of the hydrologic soil groups are in Figure I-6. A soil is assigned to two hydrologic groups if part of the acreage is artificially drained and part is undrained.

Table I-4
Soil Legend and Hydrologic Soil Group (HSG)

Description	HSG
Burchard-Nodaway complex, 2 to 30% slopes	B
Burchard clay loam, 6 to 11% slopes	B
Cold-Nodaway silty clay loams, 0 to 2% slopes	B/D
Crete silty clay loam, terrace, 1 to 3% slopes	D
Dickinson fine sandy loam, 6 to 11% slopes	A
Hedville sandy loam, 6 to 30% slopes	D
Judson silt loam, 2 to 6% slopes	B
Kennebec silt loam, 0 to 2% slopes	B
Mayberry silty clay loam, 2 to 11% slopes, eroded	D
Morrill clay loam, 6 to 11% slopes	B
Nodaway silt loam, 0 to 2% slopes	B
Nodaway silt loam, channeled	B
Pawnee clay and clay loam, 2 to 11% slopes, eroded	D
Salmo silt clay and silty clay loam, 0 to 2%	C/D
Sharpsburg silty clay loam, 2 to 9% slopes and eroded	B
Shelby clay loam, 6 to 11% slopes	B
Steinauer loam and clay loam 6% to 40% slopes	B
Wabash silty clay, 0 to 11% slopes	D
Wymore silty clay loam, 0 to 11% slopes	D
Zook silt loam and silty clay loam, 0 to 2% slopes	C/D

Resource Categorization of Nebraska's Eastern Saline Wetlands



HYDROLOGY

DESCRIPTION OF MODEL

Delineation of the study area boundary was accomplished using topographic contour mapping derived from digital aerial photography, and refined using supplemental data such as storm drain system plat maps and field verification. Subbasins were delineated in keeping with the points of interest with respect to master planning efforts, hydrologic characteristics, and areal variability requirements. The U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center in Davis, California developed a computer model (HEC-1) to evaluate hydrologic conditions.

HEC-1 can be used to analyze the impacts of projected watershed parameters on the hydrologic characteristics such as land use, soil type, and capacity of channels and ponds. The mitigating characteristics of proposed master plan components can be compared using HEC-1 analysis. The hydrologic characteristics of each subbasin are represented in the model by area in square miles, runoff curve number, and the lag time in hours.

Segmentation of the watershed into subbasins determines the number and type of stream network components. Subbasin areas range from 0.06 square miles to 0.39 square miles in size, with an average of 0.20 square miles. Reach lengths range from 50 ft to 3,000 ft with an average of 500 ft. The majority of the stream segments are in natural states. The Little Salt Creek channel from the mouth to Arbor Lake wetlands has been shaped by human actions.

HEC-1 uses the model components described below to represent the precipitation-runoff process.

Precipitation -	The amount of rainfall that occurs during a storm event.
Watershed -	The unit of land upon which water from direct precipitation, snow melt, and other storage collects in a channel and flows downhill to a common outlet.
Area -	An essential consideration in the initial evaluation of watershed hydrologic behavior.
Runoff Curve Number -	A measure of the watershed soil and cover conditions that affect runoff potential.
Time of Concentration, T_c -	The time it takes for water to travel from the most distant point on watershed to the basin outlet.
Lag -	The time between the center of mass of the rainfall excess and the peak of the unit hydrograph, a value equal to 60% of the time of concentration is used in HEC-1.
Antecedent Moisture Condition -	The amount of water stored in the soil, in small depressions, and on vegetation at the start of a hydrologic event.
Initial Abstraction -	The amount of precipitation that is absorbed or adsorbed by the soil and vegetation, respectively, before runoff occurs.

RUNOFF PARAMETERS

The amount of rainfall on a watershed that becomes runoff is dependant on many factors including; the interval since the last rain, land use, the capacity of the soil and vegetation to absorb and hold water, the type of vegetation, the percent of the area covered by pavement and rooftops, the type and condition of drainage paths (swales, channels, pipe, etc.), the rainfall duration and intensity, land slope, and watershed shape. These characteristics can be approximated using the following parameters.

Area - The size of the contributing area generating runoff that reaches a point. Drainage subbasins delineated for the watershed are shown on Figure I-8.

Runoff Curve Number - In simplistic terms, the runoff curve number is a measure of the amount of precipitation that becomes runoff. The major factors that determine runoff curve number (CN) are the hydrologic soil group, cover type (land use/ treatment), hydrologic condition, and antecedent runoff condition. Another factor considered is whether impervious areas outlet directly to the drainage system. Values of CN for average hydrologic runoff conditions for urban, cultivated agricultural, other agricultural, and arid and semi-arid range land uses are published in the Lincoln Drainage Criteria Manual (DCM), in Table 2-8 found on page 2-22, and were used to determine runoff curve numbers for the projected land uses.

Time of Concentration - Runoff curve numbers alone do not adequately reflect the effect of urbanization on stormwater systems. Runoff volume is the same for a field of small grain crops planted in straight rows in good condition as for the same field developed into 1/4-acre residential units for hydrologic soil groups B, C, and D. Urban land use provides a more efficient flow pattern (i.e., the runoff arrives at the outlet quicker). Time of concentration (T_c) for each subbasin was estimated using the procedure provided in SCS TR-55. Time of concentration was converted to lag-time for use in HEC-1.

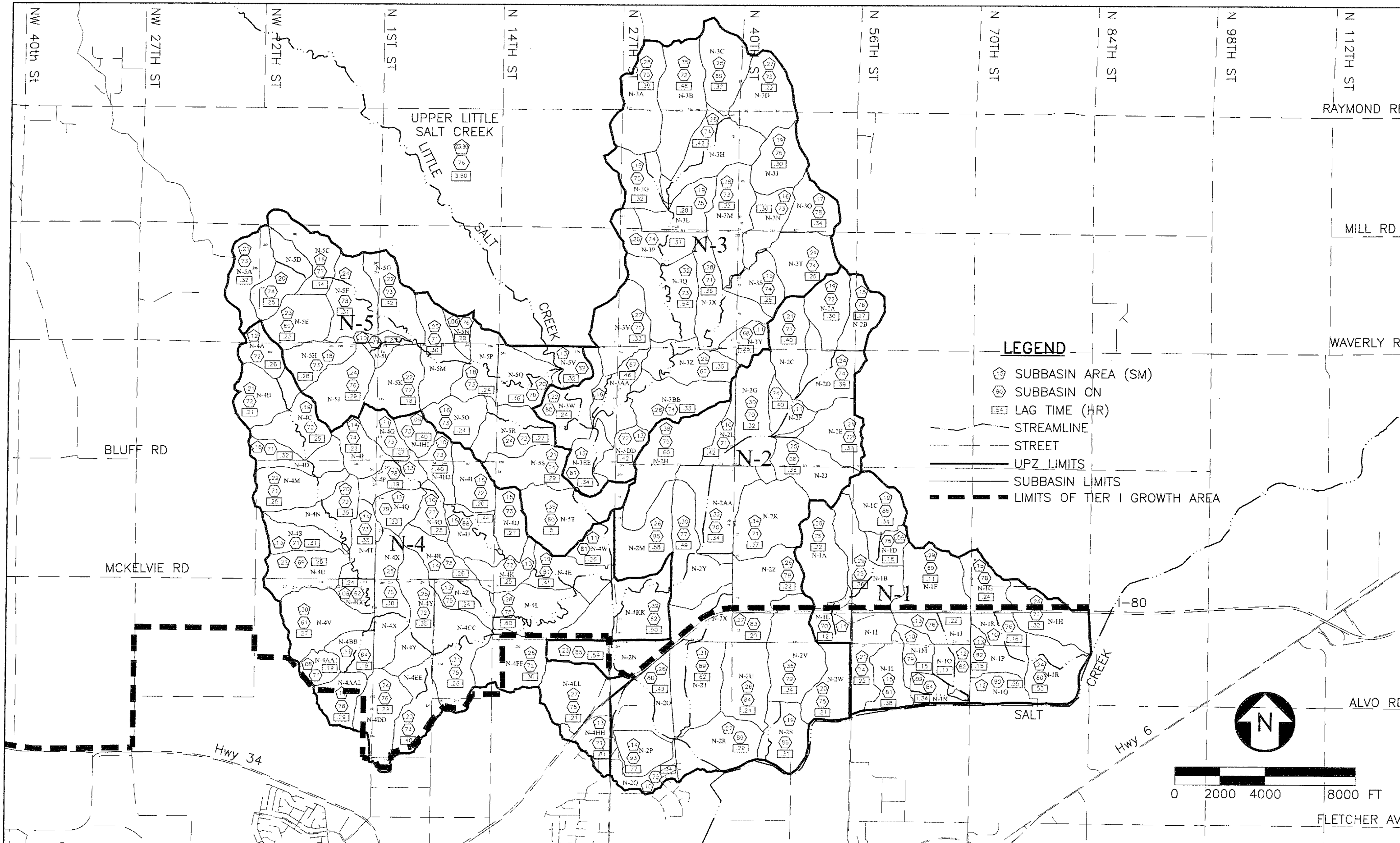
A compilation of the watershed parameters described above is given for existing conditions for UPZ N-1, N-2, N-3, N-4, and N-5 in Tables I-5a, I-5b, I-5c, I-5d and I-5e.

The runoff from each subbasin is represented by a unit hydrograph. "A unit hydrograph is the direct runoff from a unit depth of excess rainfall produced by a storm of uniform intensity and specified duration", (from Handbook of Hydrology, by David R. Maidment, page 9.26). The unit hydrograph and excess rainfall are combined to form a runoff hydrograph and the runoff hydrographs from each subbasin are routed through the reaches and combined to form a complex hydrograph at each point of interest. The complex hydrographs modeled for 2001 and projected future conditions can then be compared and used to evaluate the effectiveness of proposed stormwater management practices. A schematic outline of model components shows the sequence in which components are combined, see Figure I-9.

QUALIFICATIONS AND LIMITATIONS

Hydrologic and hydraulic procedures used for this master plan are consistent with procedures outlined in publications of the Water Environmental Federation and the American Society of Civil Engineers.

Municipal stormwater management practices are typically designed for a range of design storms with an average return period of 2-years through 500-years. The City of Lincoln requires analysis of the 5-year or 10-year for design of the minor storm drain system and the 100-year storm for design of the major storm drain system. Detention ponds are designed at a minimum to release runoff from the postdevelopment 2-, 10-, and 100-year storms at no greater than the predevelopment rate. Design storms with 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year average return periods were analyzed for this report. Summary tables generally include values for the 1-, 2- 10-, 50-, 100-, and 500-year storms. Comparison tables generally report flow values for the 2-, 10-, and 100-year storms. Water surface profiles and flood-prone areas are depicted only for the 2-, 10-, and 100-year runoff for clarity. This study does not address the effects of urbanization on ground water.



OLSSON ASSOCIATES 1111 Lincoln Mall Lincoln, NE 68508 1-402-474-6311	Lincoln, Nebraska	Hydrologic Parameters – Existing Conditions Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed	FIGURE: I-8

Table I-5a
Hydrologic Parameters UPZ N-1

Subbasin Designation	Subbasin Area (sm)	Existing Conditions		LLCCP Conditions	
		CN	T_c (hours)	CN	T_c (hours)
N-1A	0.28	75	0.53	75	0.53
N-1B	0.29	75	0.60	75	0.60
N-1C	0.19	86	0.57	86	0.57
N-1D	0.09	76	0.30	76	0.30
N-1E	0.11	70	0.20	86	0.12
N-1F	0.29	69	0.18	69	0.18
N-1G	0.15	78	0.40	78	0.40
N-1H	0.24	77	0.53	77	0.53
N-1I	0.21	74	0.37	93	0.20
N-1J	0.13	76	0.37	89	0.15
N-1K	0.10	76	0.30	89	0.12
N-1L	0.15	81	0.63	94	0.42
N-1M	0.10	79	0.25	91	0.12
N-1N	0.09	84	2.23	93	1.17
N-1O	0.12	82	0.28	82	0.28
N-1P	0.13	82	0.25	89	0.09
N-1Q	0.12	80	0.92	92	0.13
N-1R	0.24	80	0.88	80	0.88
Total	3.03				

Table I-5b
Hydrologic Parameters UPZ N-2

Subbasin Designation	Subbasin Area (sm)	Existing Conditions		LLCCP Conditions	
		CN	T_c (hours)	CN	T_c (hours)
N-2A	0.19	72	0.50	72	0.50
N-2B	0.15	76	0.45	76	0.45
N-2C	0.21	71	0.67	71	0.67
N-2D	0.24	74	0.65	74	0.65
N-2E	0.21	72	0.53	72	0.32
N-2F	0.11	74	0.67	74	0.67
N-2G	0.30	70	0.53	70	0.53
N-2H	0.38	75	1.00	75	1.00
N-2J	0.25	66	0.63	66	0.63
N-2K	0.34	71	0.62	71	0.62
N-2L	0.10	71	0.70	71	0.70
N-2M	0.26	85	0.97	85	0.97
N-2N	0.23	80	0.98	80	0.98
N-2O	0.26	86	0.82	86	0.82
N-2P	0.14	93	1.28	93	1.28
N-2Q	0.10	73	0.57	75	0.57
N-2R	0.27	89	0.48	89	0.48
N-2S	0.19	85	0.52	85	0.52
N-2T	0.31	89	1.03	89	1.03
N-2U	0.26	84	0.40	89	0.19
N-2V	0.35	79	0.57	86	0.23
N-2W	0.20	75	0.35	89	0.18
N-2X	0.27	83	0.33	87	0.18
N-2Y	0.30	77	0.82	77	0.82
N-2Z	0.26	78	0.37	78	0.37
Total	5.88				

Table I-5c
Hydrologic Parameters UPZ N-3

Subbasin Designation	Subbasin Area (sm)	Existing Conditions		LLCCP Conditions	
		CN	T_c (hours)	CN	T_c (hours)
N-3A	0.28	70	0.65	70	0.65
N-3B	0.35	72	0.77	72	0.77
N-3C	0.25	69	0.53	69	0.53
N-3D	0.27	75	0.37	75	0.37
N-3G	0.19	75	0.53	75	0.53
N-3H	0.28	74	0.70	74	0.70
N-3J	0.19	76	0.50	76	0.50
N-3L	0.19	75	0.47	75	0.47
N-3M	0.28	73	0.53	73	0.53
N-3N	0.16	73	0.50	73	0.50
N-3O	0.17	78	0.57	78	0.57
N-3P	0.20	74	0.52	74	0.52
N-3Q	0.32	73	0.90	73	0.90
N-3S	0.15	74	0.42	74	0.42
N-3T	0.24	74	0.43	74	0.43
N-3V	0.27	71	0.55	71	0.55
N-3W	0.22	80	0.40	80	0.40
N-3X	0.28	71	0.60	71	0.60
N-3Y	0.11	68	0.42	68	0.42
N-3Z	0.22	67	0.58	67	0.58
N-3AA	0.19	67	0.37	67	0.37
N-3BB	0.26	74	0.55	74	0.55
N-3DD	0.13	77	0.70	77	0.70
N-3EE	0.15	81	0.57	81	0.57
Total	5.35				

Table I-5d
Hydrologic Parameters UPZ N-4

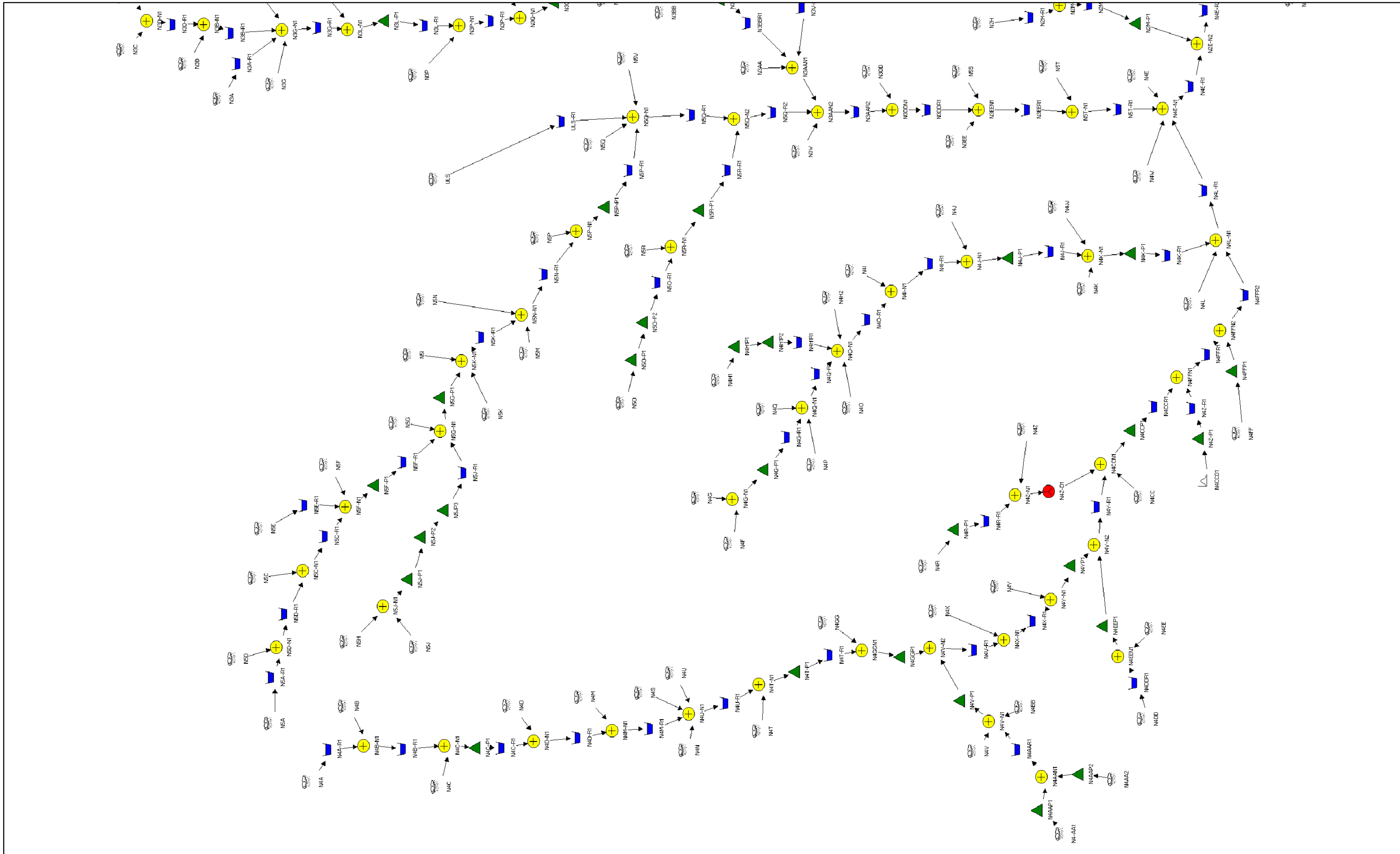
Subbasin Designation	Subbasin Area (sm)	Existing Conditions		LLCCP Conditions	
		CN	T_c (hours)	CN	T_c (hours)
N-4A	0.12	72	0.43	72	0.43
N-4B	0.21	72	0.35	72	0.35
N-4C	0.19	72	0.42	72	0.42
N-4D	0.16	71	0.53	71	0.53
N-4E	0.19	81	0.68	81	0.68
N-4F	0.14	74	0.35	74	0.35
N-4G	0.11	73	0.45	73	0.45
N-4H1	0.09	73	0.67	73	0.67
N-4H2	0.10	73	0.67	73	0.67
N-4I	0.15	72	0.33	72	0.33
N-4J	0.16	68	0.73	68	0.73
N-4K	0.13	72	0.42	72	0.42
N-4L	0.28	75	1.00	75	1.00
N-4M	0.22	71	0.42	71	0.42
N-4N	0.20	72	0.58	72	0.58
N-4O	0.10	77	0.42	77	0.42
N-4P	0.13	78	0.32	78	0.32
N-4Q	0.12	79	0.38	79	0.38
N-4R	0.14	75	0.43	75	0.43
N-4S	0.13	71	0.52	71	0.52
N-4T	0.14	73	0.55	73	0.55
N-4U	0.22	69	0.42	69	0.42
N-4V	0.30	61	0.48	61	0.48
N-4W	0.11	81	0.43	81	0.43
Subtotal	3.84				

Table I-5d (continued)
Hydrologic Parameters UPZ N-4

Subbasin Designation	Subbasin Area (sm)	Existing Conditions		LLCCP Conditions	
		CN	T_c (hours)	CN	T_c (hours)
N-4X	0.25	75	0.50	75	0.50
N-4Y	0.25	72	0.58	72	0.35
N-4Z	0.13	75	0.40	75	0.40
N-4AA1	0.08	71	0.32	71	0.32
N-4AA2	0.14	78	0.48	78	0.48
N-4BB	0.11	64	0.27	64	0.27
N-4CC	0.31	75	0.43	75	0.43
N-4DD	0.24	76	0.48	76	0.48
N-4EE	0.20	74	0.67	74	0.40
N-4FF	0.26	72	0.50	72	0.50
N-4GG	0.08	62	0.40	62	0.40
N-4HH	0.13	71	0.52	71	0.52
N-4JJ	0.15	73	0.46	73	0.46
N-4KK	0.39	82	0.83	82	0.83
N-4LL	0.27	75	0.35	75	0.35
Total	6.83				

Table I-5e
Hydrologic Parameters UPZ N-5

Subbasin Designation	Subbasin Area (sm)	Existing Conditions		LLCCP Conditions	
		CN	T_c (hours)	CN	T_c (hours)
N-5A	0.21	73	0.53	73	0.53
N-5C	0.18	77	0.23	77	0.23
N-5D	0.20	74	0.42	74	0.42
N-5E	0.23	69	0.39	69	0.38
N-5F	0.24	78	0.78	78	0.52
N-5G	0.22	73	0.70	73	0.70
N-5H	0.18	73	0.47	73	0.47
N-5I	0.10	71	0.38	71	0.38
N-5J	0.24	76	0.48	76	0.48
N-5K	0.22	77	0.30	77	0.30
N-5M	0.25	71	0.50	71	0.50
N-5N	0.06	76	0.48	76	0.48
N-5O	0.16	73	0.40	73	0.40
N-5P	0.18	73	0.40	73	0.40
N-5Q	0.20	70	0.77	70	0.77
N-5R	0.24	72	0.45	72	0.45
N-5S	0.21	74	0.48	74	0.48
N-5T	0.35	80	0.83	80	0.83
N-5V	0.13	82	0.53	82	0.53
Total	3.80				
Subtotal	24.89				
ULS	23.95	87	6.33	87	6.33
Total	48.84				



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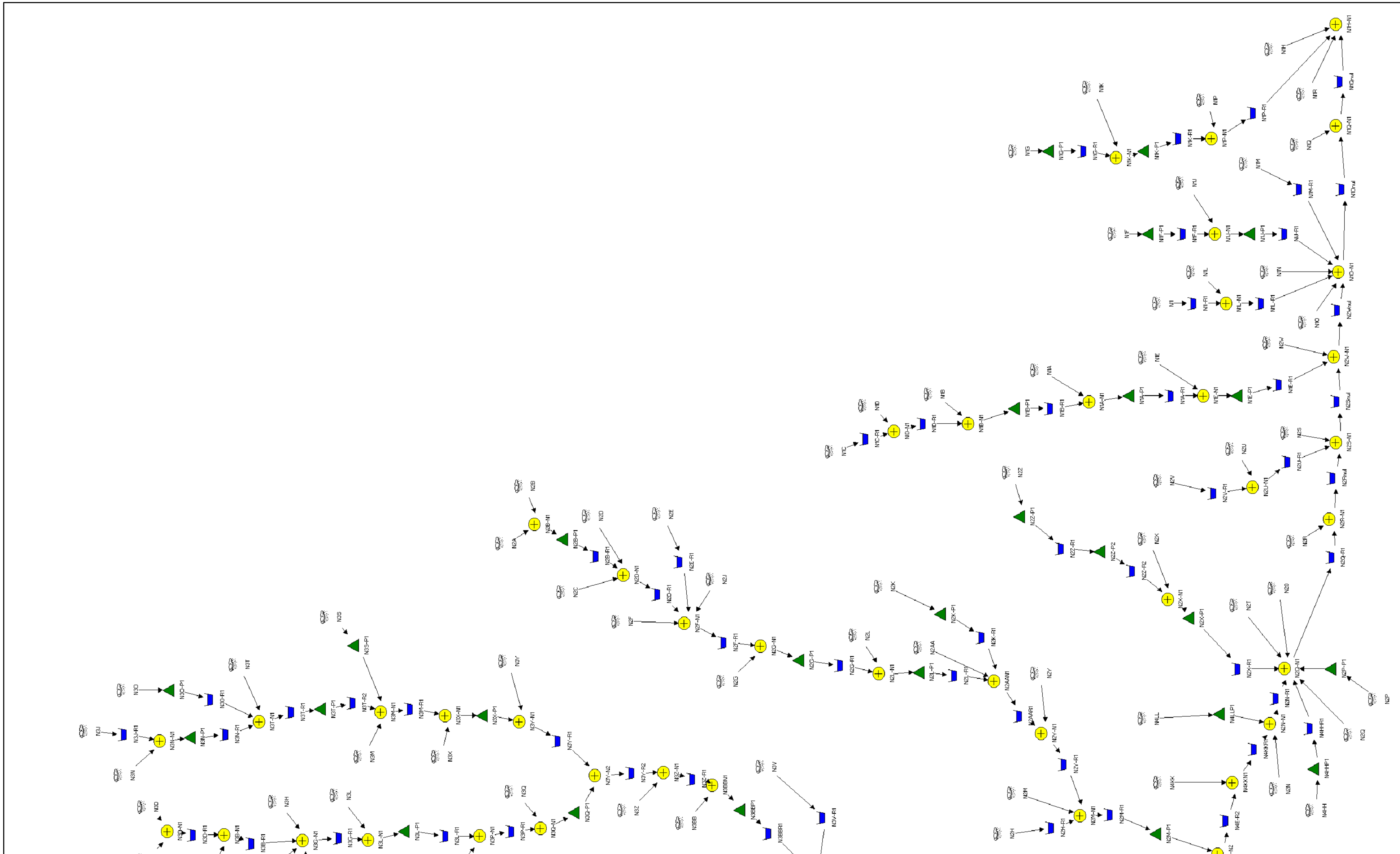
HEC-1 Model Schematic

Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed

FIGURE: I-9a



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HEC-1 Model Schematic

Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed

FIGURE: I-9b

PONDS

There are ten small ponds in the watershed model of existing conditions. Seven appear to be grade stabilization ponds, one is designed for stormwater management purposes and two are saline wetlands. Other ponds are found in the watershed but are very small and are reflected in the runoff curve number representing their subbasin. The Arbor Lake wetland storage volume is represented as storage volume for the adjoining reach. Characteristics of each modeled stormwater management pond are presented in Table I-6. For purposes of hydrologic modeling, the full flood storage volume was assumed to be available in each of the ponds at the beginning of the storm. Approximate storage volume and spillway overflow elevation data were determined from topographic contour maps.

Table I-6
Pond Characteristics

Pond Location	HEC-1 Element Number	Storage Volume at Spillway (acre-ft)	Spillway/ Overflow Elevation (ft)	Ownership and Uses
N-5J	N5J-P1	23	1,230	Private Grade Stabilization
N-5O	N5O-P1	29	1,207	Private Grade Stabilization
N-5R	N5R-P1	3	1,160	Private Grade Stabilization
N-4H1	N4H1-P1	13	1,235	Private Grade Stabilization
N-4K	N4K-P1	40	1,159	Private Grade Stabilization
N-4-AA1	N4AA-P1	17	1,261	Private Grade Stabilization
N-4-AA2	N4AA-P2	3	1,247	Private Grade Stabilization
N-4HH	N4HH-P1	60	1,242	Private Detention
N-2P	N2P-P1	70	1,134	Whitehead Saline Wetlands
N-2H	N2H-R1			Arbor Lake Wetlands

PRECIPITATION DATA

The use of design storms are a widely utilized and accepted methodology for stormwater master planning. Design storms provide a sound basis for comparison of stormwater management practices and assist in predicting the conditions under which flooding and other problems may occur. Two types of design storms are recognized, synthetic and historic. The first are derived by synthesis and generalization of a large number of actual storms. The second are events that occurred in the past and for which the impacts on the watershed may be well documented. There are no well-documented large rainfall events available for the Little Salt Creek watershed. Synthetic storm hydrographs were used to develop peak flow rates and runoff volumes to be used for comparison of the effectiveness of various stormwater management practices. The Soil Conservation Service (now called Natural Resources Conservation Service or NRCS) developed rainfall distributions for regions of the United States. Lincoln is in a region where a Type II distribution is appropriate. The 24-hour precipitation values for the 2-, 5-, 10-, 25-, 50-, and 100-year storms were obtained from Table 2-7 in the DCM prepared by the City of Lincoln and the LPSNRD. The 24-hour precipitation value for the 1-year storm was obtained from the National Weather Bureau, Technical Paper No. 40, Rainfall Frequency Atlas of the United States (TP-40). The precipitation value for the 500-year storm was determined using logarithmic extrapolation of data from TP-40.

Precipitation hydrographs are used to represent average precipitation over a computation interval. Synthetic design storm distributions were used to develop runoff hydrographs for existing conditions using the precipitation values given in Table I-7.

Table I-7
Total 24-hour Precipitation (inches)

	Average Return Period - Years							
	1	2	5	10	25	50	100	500
Total Precipitation	2.48	3.00	3.93	4.69	5.37	6.00	6.68	8.20

CALIBRATION

Stream gage records for Little Salt Creek have been maintained for 25 years. The United States Geological Survey published peak-flow frequency data for stream flow-gaging stations in Nebraska. However, the report does not provide flood duration information. For the purposes of this investigation, the HEC-1 model was calibrated against the historic (published) peak flow rates. The calibrated HEC-1 model is an effective tool to evaluate effects of urbanization on peak and volume of runoff, and assess the effectiveness of various stormwater management options.

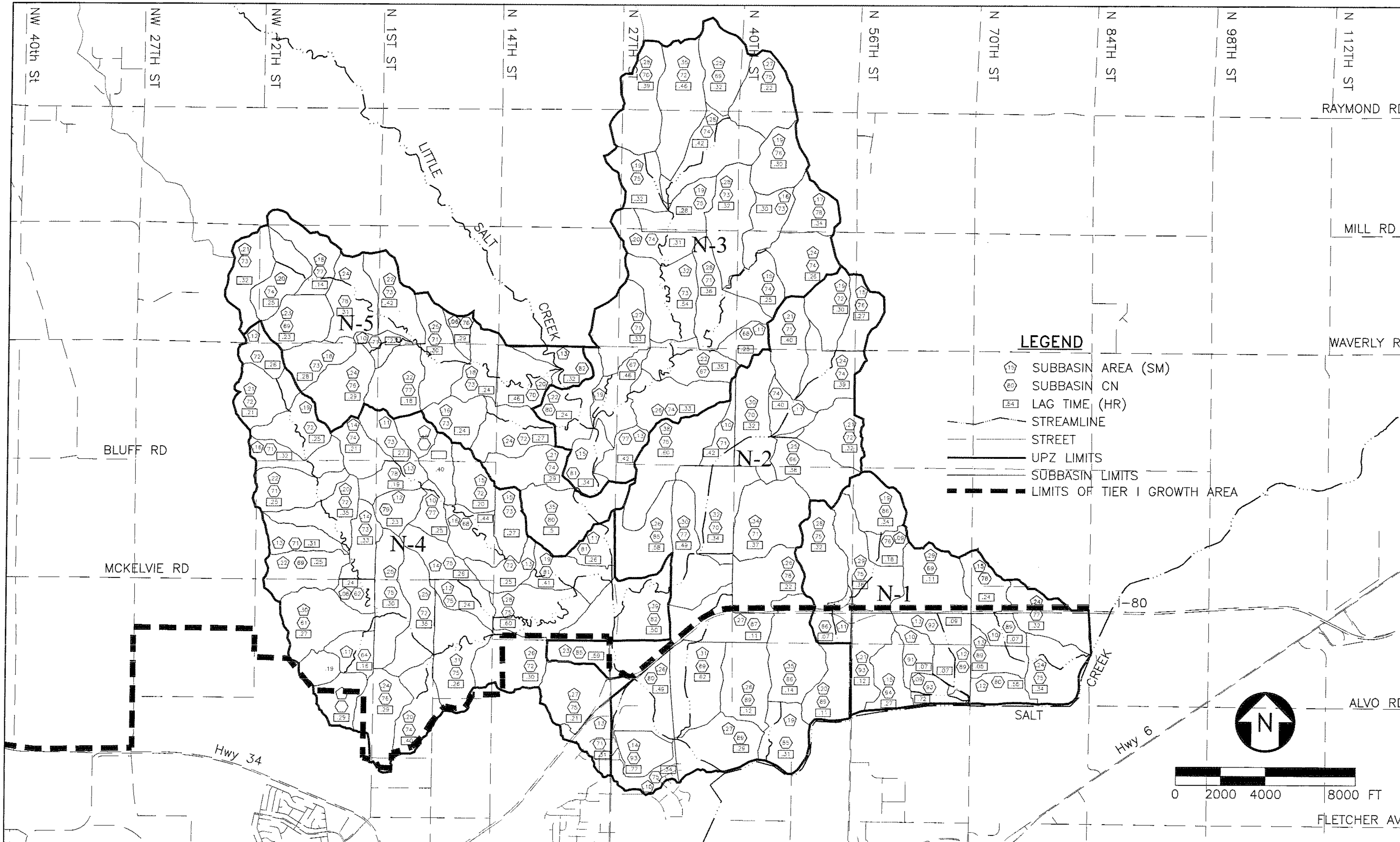
FUTURE BASIN HYDROLOGY

For the purposes of stormwater master planning in the study area, the projected land uses provided in the LLCCP for 2025 were used to determine future hydrologic characteristics. Appendix C contains a complete runoff summary of the 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year storm models for existing land use conditions and projected future land use conditions.

Area - Urbanization occasionally results in minor changes to the subbasin shape as a result of grading operations. Of course, the adjacent subbasin shape also changes. However, it is impossible to accurately forecast where future changes may occur. Therefore, for the purposes of this investigation, it was assumed that the areas of subbasins did not change due to urbanization.

Runoff Curve Number - Changes in cover type (land use) can affect the runoff curve number. Values of CN for average hydrologic runoff conditions for urban land uses, published in Figure 2-8 on page 22-2 of the Lincoln DCM, were used to determine runoff curve numbers for the projected land uses. Figure I-4 shows future land use for 2025 as projected in the LLCCP. Tables I-5a through I-5e display the runoff curve numbers used for projected future land use conditions for the LLSC watershed.

Time of Concentration - The alignment of streets and storm drains greatly affects the time of concentration. Studies have shown that the reduction in travel time can be estimated using the future CN, the percent impervious area, and the percent of the hydraulic length that is modified by development. Impervious area percentages provided in the DCM, Table 2-8, were used for future urban residential and commercial development land uses. It was assumed that 100% of the hydraulic length would be modified within each subbasin for future development, but stream channels with tributary areas greater than 150 acres would remain substantively unaltered, in accordance with the DCM. Refer to Tables I-5a through I-5e for the values of time of concentration for projected future conditions.



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Hydrologic Parameters – Projected Conditions
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FIGURE: I-10

HYDRAULICS

Channel and valley hydraulic characteristics determine the water depth generated by a given flow rate. Characteristics such as slope, available flow area, cross-section shape, degree of meander, overbank conditions, and the presence of bridges, culverts, or other crossings all effect the flow depth in a channel or flood corridor. Experience has shown that channel modifications built with the intent of increasing flow capacity, such as channel straightening or construction of levees, often have unforeseen side effects, such as channel degradation or accelerated bank sloughing. Increasing the duration, frequency, or peak rate of flow will likely result in similar undesirable changes to the channel. Natural streams in natural (i.e., unmodified) watersheds tend to reach an equilibrium condition determined by runoff and sediment. Studies have shown that in southeast Nebraska, stream channels generally have a bank-full capacity equal to the 2- to 5-year flood. Changes in the watershed or stream characteristics can cause a reaction upsetting equilibrium. For example, increased peak flow rates can result in greater depths of flow. The Corps of Engineers Hydraulic Engineering Center in Davis, California developed a River Analysis System computer model (HEC-RAS) to evaluate water surface profiles. HEC-RAS can be used to analyze the impacts of projected watershed parameters on the hydraulic characteristics of the stream channel. The mitigating characteristics of proposed master plan components can be compared using the HEC-RAS model as well.

STREAM AND TRIBUTARY MODELING

HEC-RAS allows the analysis of one-dimensional steady flow hydraulics and calculates water surface profiles. To perform these calculations the program requires channel geometric and flow data. A stream system schematic can be helpful to organize the data into a useable form and define how a stream system is connected. The watershed basin schematic generated for the Visual HEC-1 model, Figure I-9, was used to establish connectivity for the HEC-RAS model of the watershed.

Cross-Section Geometry - Cross-section locations along the stream at sufficient intervals were identified to reasonably represent the channel and overbank geometry. Cross-section data were extracted from the Triangular Irregular Network (TIN) generated by computer from aerial photography. Cross- section locations near bridges and culverts were selected to define the structure geometry. Other data for bridges and culverts were collected from digital topographic mapping, the city and county, previous studies, and through field visits. Stream cross-sections were located perpendicular to anticipated flow lines.

Energy Loss Coefficients - Energy loss coefficients are used to evaluate hydraulic energy losses. These include Manning's *n* values for channel and overbank flow, contraction and expansion coefficients for evaluation of transition losses at beginning and ending of "bottlenecks," and bridge and culvert loss coefficients to evaluate hydraulic energy losses related to bridge and culvert characteristics. The model also evaluates the hydraulic energy losses associated with stream tributary junctions.

Coordination with Existing Models - The FEMA Flood Insurance Study (FIS) of Lincoln has identified Zone "A" and Zone "X" areas in the Little Salt Creek watershed. Zone "A" is the special flood hazard area inundated by the 100-year flood event where no elevations have been determined. Zone "X" is the area determined to be outside the 500-year floodplain. Zone "A" for Little Salt Creek is delineated along the channel starting at the Salt Creek floodplain east of the abandoned Chicago and Northwest Railroads, and continuing along Little Salt Creek to Branched Oak Road. Zone "A" floodplains have also been delineated for the four main tributaries (UPZs N-2, N–3, N-4, and N-5) in the stormwater master plan area. Zone "A" on those tributaries extends up the watershed to the point where the drainage area is one square mile. The southern portion of UPZ N-1 is in Zone "AE" and Zone "X" of the Salt Creek floodplain. Zone "AE" is the special flood hazard area inundated by the 100-year flood where base flood elevations have been determined.

Information from the FIS was used to determine the starting water surface elevations in the HEC-RAS model of Little Salt Creek watershed. The main channel was modeled starting at the confluence with Salt Creek near North 40th Street extended. Tributaries were modeled from their confluence with the mainstem to the bottom of the uppermost subbasin of the LLSC watershed.

Flow Data - Values for the peak flow rates generated by Visual HEC-1 for each of the design storms were entered into the HEC-RAS model. The analysis was carried out with existing channel characteristics for the 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year average return frequency storms for existing and projected future land use conditions. Refer to Tables I-9a through I-9e for a comparison of existing condition peak flow rates for selected return periods. Peak flow rates for UPZ N-1 are provided in Table I-10. Flow rates for the LLSC watershed will be determined after further study of development impacts in the basin as recommended by the Mayor's Salt Creek Tiger Beetle Cabinet.

Road Crossing Data - Road crossing geometrics can have a considerable affect on the hydraulics of a stream. Culvert or bridge capacity determines how frequently the road will be overtopped. Roadway sag points determine the location of overtopping and are not always located above the bridge or culvert. The low chord elevation is measured at the inside top or roof of the structure. Clearance requirements between water surface and low chord elevations, known as freeboard, are frequently stipulated for bridges. Tables I-8a through I-8f provide a summary of the road crossing data for the Little Salt Creek mainstem and the N-1 through N-5 watersheds. Refer to Figures I-2 and I-9 for bridge and model element locations.

Table I-8a
Existing Road Crossing Data Summary Little Salt Creek

	Model Element		Road Crossing Elevations (ft)			
Location	HEC-1	HEC-RAS River Station (ft)	Top of Road	Low Chord	Sag Point	Size & Type
I-80 Bridge	N2N-N-1	6,386.931	1,148.9	1,144.0	1,142.0	222'x175' DSGB
I-80 Off-ramp	N2N-N-1	6,671.590	1,150.0	1,146.0	1,150.0	214' x 30' DSGB
Arbor Road	N4KK-N-1	8,754.595	1,143.3	1,141.5	1,143.3	122' x 24' DSGB

Table I-8b
Existing Road Crossing Data Summary N-1

Location	Model Element		Road Crossing Elevations (ft)			
	HEC-1	HEC-RAS River Station (ft)	Top of Road	Low Chord	Sag Point	Size & Type
Highway 77	N1B-P1	7,678.446	1,172.9	1,171.7	1,168.0	12' x 6' CBC
Interstate 80	N1A-P1	6,429.92	1,188.0	1,164.5	1,172.0	12' x 10' CBC
Arbor Road	N1E-P1	4,958.88	1,153.7	1,150.7	1,153.2	10' x 7' Twin CBC
Arbor Road *	NIJ-P1	3,238.18	1,150.6	1,141.1	1,150.0	Twin 72" CMP
Arbor Road *	NIK-P1	4,971.515	1,138.0	1,136.2	1,138.0	4.5' x 3.08' CMPA

* tributary

Table I-8c
Existing Road Crossing Data Summary N-2

Location	Model Element		Road Crossing Elevations (ft)			
	HEC-1	HEC-RAS River Station (ft)	Top of Road	Low Chord	Sag Point	Size
Arbor Road	N2X-P1	5,406.032	1,148.3	1,145.4	1,148.3	8' x 5.5' Twin CBC
I-80	N2Z-P2	6,655.664	1,160.0	1,154.5	1,160.0	9.8' X 6' CBC
Bluff Road	N2L-P1	11,664.28	1,178.0	1,176.4	1,178.0	20' x 23.2' IBB
North 40th Street	N2G-P1	13,032.78	1,186.7	1,184.7	1,186.7	12' x 6' CBC
Highway 77	N1B-P1	7,678.446	1,172.9	1,171.7	1,168.0	12' x 6' CBC
Arbor Road	N1E-P1	4,958.88	1,153.2	1,150.7	1,153.2	10' x 7' CBC

* tributary

Table I-8d
Existing Road Crossing Data Summary N-3

Location	Model Element		Road Crossing Elevations (ft)			
	HEC-1	HEC-RAS River Station (ft)	Top of Road	Low Chord	Sag Point	Size
North 27th Street	N3BBP1	2,019.034	1,152.0	1,149.9	1,152.0	12' x 10' Twin CBC
Waverly Road	N3Q-P1	7,844.06	1,175.9	1,169.9	1,172.32	12' x 12' CBC
Mill Road	N3L-P1	16,578.12	1,202.2	1,201.1	1,202.2	95" x 67" CMPA
Waverly Road	N3X-P1	1,342.985	1,174.7	1,172.3	1,174.7	10' x 8.5' CBC
North 40th Street	N3T-P1	6,519.729	1,203.0	1,201.28	1,203.0	12' x 6' CBC

Table I-8e
Existing Road Crossing Data Summary N-4

Location	Model Element		Road Crossing Elevations (ft)			
	HEC-1	HEC-RAS River Station (ft)	Top of Road	Low Chord	Sag Point	Size
North 14th Street	N4CCP1	10,971.13	1,172.0	1,169.4	1,172.0	28' x 28' DSGB
North 7th Street	N4Y-P1	15,627.0	1,185.3	1,183.0	1,185.3	8' x 5' CBC
North 1st Street	N4GGP1	19,762.18	1,206.7	1,204.1	1,206.7	12' x 7' Twin CBC
McKelvie Road	N4T-P1	22,111.29	1,214.5	1,213.1	1,214.5	8' x 6' CBC
Bluff Road	N4C-P1	30,375.41	1,258.7	1,256.2	1,258.1	8' x 6' CBC
North 14th Street	N4Z-P1	1,742.81	1,176.4	1,172.1	1,172.0	6' x 3' CBC
North 7th Street	N4EEP1	483.939	1,186.0	1,184.0	1,184.0	85" x 54" CMPA
North 1st Street	N4V-P1	664.006	1,212.0	1,208.8	1,207.1	8' x 6' Twin CBC
North 14th Street	N4J-P1	4,786.94	1,168.5	1,166.5	1,168.5	22' x 30' DSGB

Table I-8f
Existing Road Crossing Data Summary N-5

Location	Model Element		Road Crossing Elevations			
	HEC-1	HEC-RAS River Station (ft)	Top of Road	Low Chord	Sag Point	Size
North 14th Street	N5O-P2	5,124.56	1,194.0	1,187.9	1,194.0	5' x 7' CBC
North 14th Street	N5P-P1	5,784.90	1,172.5	1,171.0	1,172.0	19' x 28' DSGB
Waverly Road	N5G-P1	10,998.05	1,193.1	1,190.7	1,193.1	10' x 8.9' CBC
North 1st Street	N5F-P1	14,190.00	1,207.0	1,206.7	1,207.0	12' x 6' CBC
Waverly Road	N5J-P3	22,862.44	1,221.5	1,209.8	1,221.5	48" CMP

North 1st Street	N5J-P2	2,586.129	1,222.9	1,210.6	1,222.0	48" CMP

Abbreviation Key:

CBC	- Concrete Box Culvert	CMP	- Corrugated Metal Pipe
CCSB	- Continuous Concrete Span Bridge	IBB	- I-beam Bridge
CSB	- Concrete Slab Bridge	Dbl	- Double
Trpl	- Triple	DSGB	- Deck Steel Girder Bridge
PCGB	- Prestressed Concrete Girder Bridge	CMPA	- Corrugated Metal Pipe Arch

HEC-RAS RESULTS

The output from the HEC-RAS model includes the water surface elevation, width of flow, flow velocity, and scour energy at each cross-section. All computed flow velocities in channel reaches are subcritical with the Froude number (NF) ranging from about the 0.1's to the 0.7's, well within the acceptable boundaries. Supercritical velocities are indicated through several bridges/culverts, and immediately downstream in some instances. Scour likely occurs in the stream bed at the bridges during passage of runoff from larger storms.

HEC-RAS modeling was performed for existing and for projected LLCCP conditions in UPZ N-1. Built-out land use conditions will be modeled after a course of action for the Salt Creek Tiger Beetle habitat has been selected.

UPZ N-1 is nearing built-out conditions and all of the land is either developed, under construction, has approved preliminary plats on file, or can reasonably be expected to develop in the near future. Pending development was assumed to be in place for purposes of modeling existing conditions.

Land use conditions for the LLSC watershed are shown to remain unchanged in the "work-in-progress" LLCCP published February 6, 2002.

Peak flow rates at or near the mouth of several tributaries and mainstems decrease from upstream rates because floodplain storage is available to temporarily store flood water until the downstream channel can convey the flow. If the floodplain storage is not preserved, the flow rates would likely increase.

Stormwater master planning includes evaluation of the channels and crossing structures in the watershed, and evaluation and selection of components that meet established goals and objectives. If not anticipated, modifications to the hydrologic and hydraulic conditions may adversely affect the performance of the channels and structures.

A reach stability analysis was performed utilizing the following factors: 1) predominant stream slope versus distance from the mouth; 2) sediment transport based on bed material data; and 3) tractive force evaluation. When channel forming flows increase, stream forces will attempt to maintain a stable bed slope by either lengthening the flow path or reducing the elevation difference. The meanders are migrating outward to lengthen flow path and head cutting reducing channel slope. The majority of the stream segments have natural cross-sections. The Little Salt Creek channel shape from the mouth to Arbor Lake wetlands is a direct result of human action, such as channel straightening and head cutting. The lower portion of tributaries that discharge water into that reach of Little Salt Creek are also head cutting as a direct result of the incision of the receiving stream.

FLOOD PRONE AREAS

HEC-RAS provides a graphical interface that displays the extent of the reach subject to flooding. The information for the 2-, 10-, 100-,and 500-year events were transferred to the digital topographic mapping. Straight-line interpolation was used to determine the water surface elevations for the areas between cross-sections. The water surface profiles, along with the FEMA FIS floodplain, are shown on Figures I-11 and were projected to the valley land surface represented in the digital topographic map.

Summaries of the existing conditions peak flow rates for selected key areas in the watershed are provided in Tables I-9a through I-9g. Information is presented first for the mainstem of Little Salt Creek, then for the subbasin that discharges directly to Salt Creek, finally proceeding upstream on Little Salt Creek by subwatershed. Summaries of the LLCCP-projected conditions peak flow rates are presented in Tables I-10a through I-10g. However, to simplify comparison, only those tables with changed values are given.

Tables I-11a through I-11f compare bridge (culvert) flow capacity and frequency of overtopping for the bridge and culverts in the LLSC watershed. Data are presented in the same order as the flow rate tables. This information can be used to prioritize replacement as part of a capital improvement program.

Tables I-12a through I-12c compare the peak flow rates for existing and LLCCP-projected conditions. Data are presented at selected locations in the LLSC watershed. Only those locations on tributaries in the Tier 1 subbasins of UPZs N-1 and N-2 are presented. Modeled changes in the peak rate of flow range from about 17% to nearly 300% due to projected urbanization.

Table I-9a
Existing Conditions Peak Flow Rate Values (cfs) at Selected Locations on the Little Salt Creek Mainstem

	Model Identifier		Average Return Period, years					
Location	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
Waverly Road	ULS	27,140	2,519	3,414	6,481	8,924	10,199	13,059
DS Junction UPZ	N5Q-N-1	24,576	2,603	3,524	6,783	9,389	10,769	13,863
US Junction UPZ	N5Q-N-2	21,447	2,609	3,534	6,808	9,422	10,805	13,918
DS Junction UPZ	N3AAN-2	19,934	2,783	3,775	7,240	10,148	11,642	15,005
US Junction UPZ	N5T-N-1	14,055	2,795	3,796	7,265	10,054	11,649	15,040
DS Junction UPZ	N4E-N-1	10,830	2,973	4,088	7,825	11,118	12,656	16,639
DS Junction UPZ	N2E-N-2	9,602	3,054	4,212	8,057	11,408	12,687	17,025
Arbor Road	N2KKN-1	8,754	3,063	4,226	8,082	11,415	12,626	17,047
Interstate 80	N2N-N-1	6,197	3,067	4,246	8,122	11,217	12,355	16,933
DS Junction N2T	N2Q-N-1	2,017	3,096	4,298	8,111	10,647	11,865	15,656
Mouth	N2R-N-1	827	3,096	4,306	8,074	10,365	11,469	15,519

Table I-9b
Existing Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-1 Tributaries

Location	Model Identifier		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
N-1 Tributary								
Highway 77	N1B-N1	7678.446	199	304	672	983	1,153	1,519
Interstate 80	N1A-N1	6424.920	208	303	798	1,281	1,544	1,932
Arbor Road	N1E-N1	4958.880	212	310	787	1,166	1,348	1,603
N-1 Tributary								
Arbor Road	N1J-N1	3238.180	93	159	398	523	594	769
N-1 Tributary								
Arbor Road	N1K-N1	4971.515	90	145	315	433	503	662

Table I-9c
Existing Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-2 Mainstem and Tributaries

Location	Model Identifier		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
N-2								
Waverly Road	N2B-R1	18,242	88	139	329	560	667	978
North 40th Street	N2G-N1	13,075	242	417	1,177	1,866	2,256	3,181
Bluff Road	N2L-P1	11,603	242	383	911	1,811	2,257	3,235
Old C&NW RR	N2AAN1	5,361	284	455	1,051	2,037	2,584	3,840
US Salt Creek	N2M-N1	2,068	320	551	1,308	2,318	2,924	4,301
N-2 Tributary								
North 48th Street	N2Z-P1	8,352	112	165	362	546	636	853
Interstate 80	N2Z-P2	6,528	106	165	335	578	645	840
Arbor Road	N2X-P1	5,233	185	264	551	785	907	1,188

Table I-9d
Existing Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-3 Mainstem and Tributaries

Location	Model Identifier		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
N-3								
Confluence Trib 3,4,5	N3B-N1	18,690	163	272	724	1,131	1,353	1,871
Mill Road	N3G-N1	17,620	275	457	1,196	1,874	2,238	3,107
Waverly Road	N3Q-N1	7,897	224	385	1,135	1,879	2,302	3,283
DS Junction Trib 2	N3Y-N2	6,830	355	570	1,490	2,308	2,780	4,219
North 27th Street	N3BBP1	2,064	357	573	1,488	2,326	2,813	4,234
DS Junction Trib 1	N3AAN1	360	365	586	1,528	2,384	2,879	4,264
N-3 Tributary 1								
Reach	N3V-R1	2,410	46	81	244	380	452	641
Junction N3								
N-3 Tributary 2								
Reach	N3T-N1	8,165	166	258	621	968	1,159	1,564
North 40th Street	N3T-P1	6,388	166	258	621	968	1,159	1,564
Waverly Road	N3X-N1	1,392	170	264	583	888	1,023	1,521
US Junction N3	N3Y-N1	1,069	169	263	576	843	1,027	1,533

Table I-9e
Existing Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-4 Mainstem and Tributaries

Location	Model Identifier		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
N-4								
Bluff Road	N4C-N1	30,413	98	173	493	768	917	1,279
McKelvie Road	N4T-N1	22,177	124	214	617	1,092	1,393	2,170
North 1st Street	N4GGP1	19,797	117	206	612	1,089	1,402	2,173
North 7th Street	N4Y-N1	15,668	137	243	777	1,429	1,826	2,839
North 14th Street	N4CCN1	11,017	179	326	1,079	1,822	2,284	3,396
US Junction N4 Trib 2	N4CCP1	10,925	176	327	1,063	1,736	2,180	3,368
DS Junction N4 Trib 2	N4FFN2	8,326	198	406	1,230	1,883	2,330	3,544
DS Junction N4 Trib 1	N4L-N1	1,707	200	391	1,481	2,046	2,456	3,929
N-4 Tributary								
Bluff Road	N4G-N1	12,715	72	120	308	470	558	759
North 14th Street	N4J-N1	4,827	176	298	802	1,257	1,494	2,067
Junction N4	N4K-N1	1,854	171	276	700	1,078	1,245	1,765
N-4 Tributary								
North 14th Street	N4Z-N1	1,777	59	90	223	369	465	647
Junction N4								
N-4 Tributary								
North 7th Street	N4EEN1	512	121	191	481	725	857	1,156
Junction N4								
N-4 Tributary								
North 1st Street	N4V-P1	1,719	23	62	286	516	635	964
Junction N4								

Table I-9f
Existing Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-5 Mainstem and Tributaries

Location	Model Identifier		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
N-5								
North 1st Street	N5F-N1	14,265	202	330	843	1,326	1,580	2,159
US Junction Trib 1	N5F-P1	14,115	161	260	679	1,215	1,473	2,124
Waverly Road	N5G-N1	11,381	181	289	662	950	1,413	2,237
North 14th Street	N5N-N1	7,617	228	352	793	1,138	1,479	2,399
US Junction L Salt	N5P-R1	5,740	218	342	788	1,133	1,426	2,248
N-5 Tributary 1								
North 1st Street	N5J-P1	2,924	7	10	92	243	328	518
Waverly Road	N5J-P2	2,520	7	10	90	147	155	291
US Junction N5	N5J-P3	2,356	7	10	87	133	155	291
N-5 Tributary								
North 14th Street	N5O-P1	5,482	4	6	13	17	18	41
US Junction L Salt	N5R-N1	2,614	57	97	255	395	470	646

Table I-9g
Existing Conditions Peak Flow Rate Values (cfs) at Selected Locations for Subbasins Discharging Directly to Salt Creek

Location	Model Identifier		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
See Figure I-8	N2W	N/A	72	116	280	421	496	667
See Figure I-8	N1L-R1	N/A	100	162	393	588	696	950
See Figure I-8	N1M-R1	N/A	32	50	117	180	212	285
See Figure I-8	N1M	N/A	19	27	53	74	86	111
See Figure I-8	N1O	N/A	79	112	227	319	367	474
See Figure I-8	N1Q	N/A	36	53	116	167	195	256
See Figure I-8	N1R	N/A	74	109	238	344	400	526

See Figure I-8	N1H	N/A	81	126	292	432	506	675

Table I-10a
LLCCP-Projected Conditions Peak Flow Rate Values (cfs) at Selected Locations on the Little Salt Creek Mainstem
Land Use Not projected to Change - See Table I-9a

Table I-10b
LLCCP-Projected Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-1 Tributaries

Location	Model Identifier		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
N-1 Tributary								
Highway 77	N1B-P1	7,678	169	242	601	944	1,113	1,298
Interstate 80	N1A-P1	6,425	208	304	783	1,153	1,330	1,566
Arbor Road	N1E-P1	4,959	218	316	790	1,152	1,314	1,600
N-1 Tributary								
Arbor Road	N1J-P1	3,238	157	205	418	615	673	760
N-1 Tributary								
Arbor Road	N1K-P1	4,972	128	178	367	516	586	734

Table I-10c
LLCCP-Projected Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-2 Tributaries

Location	Model Element		Average Return Period, years					
	HEC-1	HEC- RAS River Station (ft)	1	2	10	50	100	500
N-2								
Waverly Road	N2B-R1	18,242.00	88	139	329	560	667	978
North 40th Street	N2G-N1	13,075.00	242	417	1,177	1,866	2,256	3,181
Bluff Road	N2L-P1	11,603.00	242	383	911	1,811	2,257	3,235
Old C & NW RR	N2AAN1	5,361.00	284	455	1,051	2,037	2,584	3,840
US Salt Creek	N2M-N1	2,068.00	320	551	1,308	2,318	2,924	4,301
N-2 Tributary								
North 48th Street	N2Z-P1	8,352.00	112	165	362	546	636	853
Interstate 80	N2Z-P2	6,528.00	106	165	335	578	645	840
Arbor Road	N2X-P1	5,233.00	284	385	728	1,001	1,142	1,456

Table I-10d
LLCCP-Projected Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-3 Tributaries
Land Use Not projected to Change - See Table I-9d

Table I-10e
LLCCP-Projected Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-4 Tributaries
Land Use Not projected to Change - See Table I-9e

Table I-10f
LLCCP-Projected Conditions Peak Flow Rate Values (cfs) at Selected Locations on UPZ N-5 Tributaries
Land Use Not projected to Change - See Table I-9f

Table I-10g
LLCCP-Projected Conditions Peak Flow Rate Values (cfs) at Selected Locations for Subbasins Discharging Directly to Salt Creek

Location	Model Identifier	Average Return Period, years					
	HEC-1	1	2	10	50	100	500
See Figure I-10	N2W	232	305	545	731	826	1,039
See Figure I-10	N1L-N1	355	456	791	1,040	1,169	1,456
See Figure I-10	N1M-R1	78	102	193	261	296	373
See Figure I-10	N1N	50	63	107	140	158	196
See Figure I-10	N1O	79	112	227	319	367	474
See Figure I-10	N1Q	166	211	357	468	526	654
See Figure I-10	N1R	74	109	238	344	400	526
See Figure I-10	N1H	81	126	292	432	506	675

Table I-11a
Comparison of Bridge Flow Capacity for Little Salt Creek (cfs)

	Model Identifier		100-year Flow			Average Return Frequency [2]	
Location	HEC-1	Size and Type	Existing	Projected	Capacity [1]	Existing	LLCCP-Projected [3]
Little Salt Creek							
Arbor Road	N4KK-N1	122 x 24 DSGB	12,626	12,626	15,800	Á100	Á100
Interstate 80	N2N-N1	222 x 175 DSGB	12,355	12,355	17,000	500	500
Interstate 80	N2N-N1	214 x 30 DSGB	12,355	12,355	17,000	500	500

1. Capacity for stormwater master planning purposes is defined as the flow rate that occurs prior to roadway overtopping.
2. Number of years (on average) that can be expected between overtopping events. For example, a bridge has a capacity before overtopping the road of 600 cfs, the 10% return frequency storm (10-year) flow rate is listed as 660 cfs and the 20% return frequency storm (5-year) flow rate is 540 cfs. By interpolation on probability paper, the bridge capacity would be less than the 10% return frequency storm or on average the bridge can be expected to be overtopped more frequently than every 10 years based on flow rates.
3. Value for existing structure with flow rates for projected conditions yet to be determined at publication.

Table I-11b
Comparison of Bridge Flow Capacity for UPZ N-1 (cfs)

	Model Identifier		100-year Flow			Average Return Frequency	
Location	HEC-1	Size and Type	Existing	Projected	Capacity	Existing	LLCCP-Projected
N-1 Tributary							
Highway 77	N1B-P1	12' x 6' CBC	1,153	1,113	150	<1	<1
Interstate 80	N1A-P1	12' x 10' CBC	1,544	1,330	2,050	>500	>500
Arbor Road	N1E-P1	10' x 7' Twin CBC	1,348	1,314	1,550	>100	>100
N-1 Tributary							
Arbor Road	N1J-P1	Twin 72" CMP	594	673	850	>100	>100
N-1 Tributary							
Arbor Road	N1K-P1	4.5' x 3.1' CMPA	503	586	367	>10	10

Table I-11c
Comparison of Bridge Flow Capacity for UPZ N-2 (cfs)

	Model Identifier		100-year Flow			Average Return Frequency	
Location	HEC-1	Size and Type	Existing	Projected	Capacity	Existing	LLCCP-Projected
N-2							
North 40th Street	N2G-N1	12' x 6' CBC	2,256	2,256	790	5	5
Bluff Road	N2L-N1	20' x 23.2' IBB	2,257	2,257	1,750	50	50
N-2 Tributary							
Interstate 80	N2Z-P2	9.8' X 6' CBC	645	645	810	Á100	Á100
Arbor Road	N2X-P1	8' x 5.5' Twin CBC	907	1,142	900	100	<100

Table I-11d
Comparison of Bridge Flow Capacity for UPZ N-3 (cfs)

	Model Identifier		100-year Flow			Average Return Frequency	
Location	HEC-1	Size and Type	Existing	Projected	Capacity	Existing	LLCCP-Projected
N-3							
Mill Road	N3L-N1	95" x 67" CMPA	2,238	2,238	270	1	1
Waverly Road	N3Q-N1	12' x 12' CBC	2,302	2,302	2,060	50	50
North 27th Street	N3BB-P1	12' x 10' Twin CBC	2,813	2,813	2,280	75	75
N-3 Tributary							
North 40th Street	N3T-N1	12' x 6' CBC	1,159	1,159	580	10	10
Waverly Road	N3M-R1	10' x 8.5' CBC	1,023	1,023	880	50	50

Table I-11e
Comparison of Bridge Flow Capacity for UPZ N-4 (cfs)

Location	Model Identifier	Size and Type	100-year Flow		Capacity	Average Return Frequency	
	HEC-1		Existing	Projected		Existing	LLCCP-Projected
N-4							
Bluff Road	N4C-N1	8' x 6' CBC	917	917	470	10	10
McKelvie Road	N4T-N1	8' x 6' CBC	1,393	1,393	810	20	20
North 1st Street	N4GGP1	12' x 7' Twin CBC	1,402	1,402	2,300	Á100	Á100
North 7th Street	N4Y-N1	8' x 5' CBC	1,826	1,826	950	15	15
North 14th Street	N4CCN1	28'' x 28'' DSGB	2,284	2,284	2,230	100	100
N-4 Tributary							
North 14th Street	N4J-N1	22'' x 30'' DSGB	1,494	1,494	1,460	100	100
N-4 Tributary							
North 14th Street	N4Z-N1	6' x 3' CBC	465	465	90	2	2
N-4 Tributary							
North 7th Street	N4EEN1	81' x 54' CMPA	857	857	140	1	1
N-4 Tributary							
North 1st Street	N4V-P1	8' x 6' twin CBC	635	635	934	500	500

Table I-11f
Comparison of Bridge Flow Capacity for UPZ N-5 (cfs)

Location	Model Identifier	Size and Type	100-year Flow		Capacity	Average Return Frequency	
	HEC-1		Existing	Projected		Existing	LLCCP-Projected
N-5							
North 1st Street	N5F-N1	12' x 6' CBC	1,580	1,580	550	4	4
Waverly Road	N5G- P1	10' x 8.9' CBC	1,413	1,413	940	50	50
North 14th Street	N5N-P1	19' x 28' DSGB	1,479	1,479	980	20	20
N-5 Tributary 1							
North 1st Street	N5J-P1	48" CMP	328	328	170	25	25
Waverly Road	N5J-P3	48" CMP	155	155	290	150	150
N-5 Tributary							
North 14th Street	N5O-P2	5' x 7' CBC	18	18	200	Á500	Á500

Table I-12a
2-year Peak Flow Rate Values at Selected Locations in the Lower Little Salt Creek Watershed

Location	Model Identifier		Existing	Projected	
	HEC-1	HEC-RAS River Station (ft)	Q, cfs	Q, cfs	% Increase
N-1 Tributary					
Arbor Road	N1K-N1	4,971.515	145	178	23%
N-2 Tributary					
North 48th Street	N2Z-P1	835.699	165	165	0%
Interstate 80	N2Z-P2	6,528.950	165	165	0%
Arbor Road	N2X-N1	5,233.652	264	385	46%
Direct Discharge to Salt Creek					
See Figure I-10	N2W	N/A	116	305	163%
See Figure I-10	N1L-N1	N/A	162	456	181%
See Figure I-10	N1M-R1	N/A	50	102	104%
See Figure I-10	N1M	N/A	27	63	133%
See Figure I-10	N1O	N/A	112	112	0%
See Figure I-10	N1Q	N/A	53	211	298%
See Figure I-10	N1R	N/A	109	109	0%
See Figure I-10	N1H	N/A	126	126	0%

Table I-12b
10-year Peak Flow Rate Values at Selected Locations in the Lower Little Salt Creek Watershed

Location	Model Identifier		Existing	Projected	
	HEC-1	HEC-RAS River Station (ft)	Q, cfs	Q, cfs	% Increase
N-1 Tributary					
Arbor Road	N1K-N1	4,971.515	315	367	17%
N-2 Tributary					
North 48th Street	N2Z-P1	835.699	362	362	0%
Interstate 80	N2Z-P2	6,528.950	335	335	0%
Arbor Road	N2X-N1	5,233.652	551	728	32%
Direct Discharge to Salt Creek					
See Figure I-10	N2W	N/A	280	545	95%
See Figure I-10	N1L-N1	N/A	393	791	101%
See Figure I-10	N1M-R1	N/A	117	193	65%
See Figure I-10	N1M	N/A	53	107	102%
See Figure I-10	N1O	N/A	227	227	0%
See Figure I-10	N1Q	N/A	116	357	208%
See Figure I-10	N1R	N/A	238	238	0%
See Figure I-10	N1H	N/A	292	292	0%

Table I-12c
100-year Peak Flow Rate Values at Selected Locations in the Lower Little Salt Creek Watershed

Location	Model Identifier		Existing	Projected	
	HEC-1	HEC-RAS River Station (ft)	Q, cfs	Q, cfs	% Increase
N-1 Tributary					
Arbor Road	N1K-N1	4,971.515	503	586	17%
N-2 Tributary					
North 48th Street	N2Z-P1	835.699	636	636	0%
Interstate 80	N2Z-P2	6,528.950	645	645	0%
Arbor Road	N2X-N1	5,233.652	907	1142	26%
Direct Discharge to Salt Creek					
See Figure I-10	N2W	N/A	496	826	67%
See Figure I-10	N1L-N1	N/A	696	1169	68%
See Figure I-10	N1M-R1	N/A	212	296	40%
See Figure I-10	N1M	N/A	86	158	84%
See Figure I-10	N1O	N/A	367	367	0%
See Figure I-10	N1Q	N/A	195	526	170%
See Figure I-10	N1R	N/A	400	400	0%
See Figure I-10	N1H	N/A	506	506	0%

EVALUATION

All projected land use changes in the LLSC watershed east of 27th Street occur south of Interstate 80. Projected land use changes west of 27th Street occur south of Arbor Road. Areas east of 48th Street flow directly into Salt Creek, the rest flow directly into Little Salt Creek. These areas are identified as Tier 1 growth areas identified in the LLCCP (refer back to Land Use discussion near the beginning of this report). The four subwatersheds (most of N-2 and all of N-3, N-4, and N-5) that discharge to Little Salt Creek do not have projected land use changes.

Land use changes projected in the LLCCP for UPZ N-1 and parts of UPZ N-2 would increase peak flow rates from the subbasins in those areas. As these subbasins urbanize, each development would be required to limit runoff at the property line after development to predevelopment rates. Typically this requirement is met using stormwater storage facilities (detention ponds). In some specific locations, when it has been clearly demonstrated to the City that detention would be detrimental, the detention requirement has been waived.

Most of the subbasins, which are projected to urbanize, drain directly to Salt Creek. Several of those are in the FIS delineated floodplain of Salt Creek. Three tributaries in UPZs N-1 and N-2 convey runoff from subbasins north of Interstate 80 to Salt Creek and have subbasins that are expected to urbanize. For performance evaluation purposes, concept detention ponds were added to the watershed model at the outlet of Subbasins N-2X, N-1E and N-1K. The NRCS TR-55 procedure for quick estimation of storage volume requirements for a known release rate was used to approximate operating characteristics of such detention ponds. A summary of these characteristics for the initial detention concept in those subbasins is listed in Table I-13.

Table I-13
Detention Pond Approximate Operating Characteristics

Concept Location (HEC-1 Model ID)	Characteristic Description	2-year	10-year	100-year
Subbasin N-1E Outlet	Projected peak inflow rate, cfs	155	287	444
	Peak outflow rate, cfs (& existing peak inflow)	53	153	290
	Approximate Storage Volume, acre-ft	3.5	5.1	6.4
Subbasin N-2X Outlet	Projected peak Inflow rate, cfs	379	702	1,083
	Peak outflow rate, cfs (& existing peak inflow)	255	511	822
	Approximate Storage Volume, acre-ft	5.5	9.4	14.1
Subbasin N-1K Outlet	Projected peak Inflow rate, cfs	158	279	424
	Peak outflow rate, cfs (& existing peak inflow)	66	153	266
	Approximate Storage Volume, acre-ft	3.1	4.9	6.9

For Subbasins N-2X, N-1E, and N-1K, Tables I-14a, I-14b, and I-14c summarize modeled peak flow rates (Q_p)and time to peak (T_p) for existing land use conditions, and for LLCCP-projected land use conditions with and without trial detention ponds. Tables I-14a and I-14c show that concept detention modeled in subbasins N-2X and and N-1K gave the expected result of limiting postdevelopment peak flow rates to or below existing peak flow rates.

Table I-14b shows that modeling gave an unexpected result for detention concepts in Subbasin N-1E. For Subbasin N-1E, each of the three modeled detention concepts resulted in higher than projected condition peak flows at the location where flow from the subbasin joins the tributary. This occurred because slowing the basin outflow by use of detention made the time to peak coincident with that of the tributary. The results presented in Table I-14b for Subbasin N-1E illustrates the need for holistic evaluation of detention pond effects. It shows that even though a detention pond meets or exceeds the minimum release rate criteria it may increase peak flow rates downstream in the watershed. In the situation projected to occur in Subbasin N-1E it may be better to not detain flow from this subbasin.

Table I-14a
Summary for Concept Detention in Subbasin N-2X

HEC-1 Model ID	Land Use Condition	2-year		10-year		100-year	
		Q_p, cfs	T_p (hr)	Q_p, cfs	T_p (hr)	Q_p, cfs	T_p (hr)
N-2X Outlet	Existing	255	12.10	511	12.10	822	12.10
Subbasin	Projected	379	12.00	702	12.00	1,083	12.00
	Detention 1*	220	12.10	466	12.10	748	12.10
N-2X-N-1	Existing	264	12.10	551	12.10	907	12.10
Junction at Outlet	Projected	385	12.00	728	12.00	1,142	12.00
N-2X	Detention 1*	262	12.50	509	12.20	833	12.20

* Detention Concept 1 - Release rate equal to predevelopment rate

Table I-14b
Summary for Concept Detention in Subbasin N-1E

HEC-1 Model ID	Land Use Condition	2-year		10-year		100-year	
		Q_p, cfs	T_p (hr)	Q_p, cfs	T_p (hr)	Q_p, cfs	T_p (hr)
N-1E Outlet	Existing	53	12.00	153	12.00	290	12.00
	Projected	155	12.00	287	12.00	444	12.00
	Detention 1*	50	12.20	185	12.10	337	12.00
	Detention 2**	24	12.40	79	12.20	175	12.10
	Detention 3***	13	12.80	27	12.60	89	12.30
N-1E-N-1	Existing	310	12.70	787	12.50	1,348	12.60
	Projected	315	12.70	792	12.50	1,350	12.60
	Detention 1*	339	12.60	824	12.50	1,390	12.50
	Detention 2**	325	12.70	827	12.50	1,422	12.50
	Detention 3***	314	12.70	787	12.60	1389	12.60

* Detention Concept 1 - Release rate equal to predevelopment rate
** Detention Concept 2 - Release rate equal to 50% of predevelopment rate
*** Detention Concept 3 - Release rate equal to 25% of predevelopment rate

Table I-14c
Summary for Concept Detention in Subbasin N-1K

HEC-1 Model ID	Land Use Condition	2-year		10-year		100-year	
		Q_p, cfs	T_p, hr	Q_p, cfs	T_p, hr	Q_p, cfs	T_p, hr
N-1K	Existing	66	12.10	153	12.10	266	12.10
	Projected	158	12.00	279	12.00	424	11.90
	Detention 1*	65	12.10	164	12.10	276	12.10
	Detention 2**	32	12.30	77	12.20	137	12.20
N-1K-N-1	Existing	145	12.20	315	12.10	503	12.10
	Projected	178	12.00	367	12.00	586	12.00
	Detention 1*	158	12.20	339	12.20	530	12.20
	Detention 2**	129	12.30	272	12.20	455	12.30

* Detention Concept 1 - Release rate equal to predevelopment rate
** Detention Concept 2 - Release rate equal to 50% of predevelopment rate

From tables I-9 and I-10, the increase in runoff peak flow rates in the Tier 1 subbasins is projected to range from about 17% to nearly 300% due to urbanization. The largest changes are projected to occur in those subbasins that drain directly to Salt Creek. They are projected to change from agricultural to commercial and industrial land use. Impervious area could change from 0% to 85% and the open drainageways would typically be converted from open channel to enclosed storm drain pipes. The stormwater management system in these subbasins would need to be carefully planned and developed to avoid the stormwater infrastructure quality, environmental and flooding problems, which have been experienced in previously developed City of Lincoln stormwater basins.

In addition, subbasins that drain directly to Salt Creek will need to be planned to anticipate and address stream erosion and degradation as runoff from urbanized areas flows and falls to the incised channel of Salt Creek.

Insert Figure I-11
Flood Hazard Map
Lower Little Salt Creek Watershed

STREAM SEGMENT EVALUATION

Stormwater master planning includes evaluation of the channels and crossing structures in the watershed. If not anticipated, modifications to the hydrologic and hydraulic conditions may adversely affect the performance of the channels and structures.

Channel Stability

Channel stability is important not only as a safety issue but also from a water quality standpoint. A degrading channel causes bank sloughing, which can reduce tillable land in agricultural areas or threaten adjacent infrastructures in urban areas. Bank failure is also a significant source of sediment in many urban streams.

The 2- to 5-year storm events are considered to provide channel forming flows. They occur relatively frequently and have sufficient energy to determine the shape and slope of the channel. When channel forming flows increase, stream forces will attempt to maintain a stable bed slope by either lengthening the flow path or reducing the elevation difference. Meanders migrate outward to lengthen the flow path and head cuts reduce channel slope.

A reach stability analysis was performed utilizing a process outlined in the NRCS "Stream Corridor Restoration Manual", which uses the following factor; bend radius, flow width and depth, soil classification, plasticity index, and void ratios. Conclusion of the evaluation process supports field observations. Observations of channel stability were made from or adjacent to public right-of way or public property.

Flood Hazard

The hazard due to flooding is determined by hydrology and stream and valley shape (a.k.a. "the lay of the land"), channel restrictions, channel crossings, proximity of buildings, and flow rates.

Threats to Infrastructure

Infrastructure includes road and railroad bridges or culverts, and buried or overhead utilities. Road crossings cannot only influence flooding but can be threatened by flooding. Refer to Tables I-13a, I-13b and I-13c for roadway overtopping frequency values. In addition to flooding, localized scour and head cutting can undermine the stability of bridges or culverts. Utilities are often installed parallel to or across stream channels. Channel meandering can threaten adjacent buried conduits or support towers for overhead utilities. Head cutting can expose buried utilities in stream beds. Utility crossings often share or are near road ROWs. Road crossings can either protect the utility (i.e., a box culvert providing a local hardpoint) or accelerate erosion (i.e., increased stream velocities causing local scour).

Land Use and Ownership

Existing or projected land use and ownership of property adjacent to streams is an important consideration in stormwater master planning. For example, channel improvements or maintenance activities may be facilitated by a channel easement along a stream or public park adjacent to the stream.

Multi-Purpose Use Potential

An important benefit of master planning is the opportunity to coordinate the efforts of several interests such as private developers, city, county, NRD, and other agencies. For example, coordinating existing and potential future public open space along stream channels. Stream corridors can serve alternately as both connectors and as separators. They provide connective habitat for movement of wildlife and provide recreation trail opportunities. Riparian areas serve as boundaries and edges and riparian forests shade streams. Flood waters can be temporarily stored along channels until downstream capacity can drain the runoff volume. Riparian buffers can filter surface runoff and provide opportunities for nutrient uptake.

Water Quality

Land use has been shown to affect stormwater runoff water quality. Accessing adjacent land use or projected land use can provide an indicator of potential water quality concerns.

THREAT MATRIX

The following ranking protocol was used to determine the relative threat to the stream segments in the basins.

Reach Stability

High	- Active bed or bank erosion
Medium	- Few indicators of active bed or bank erosion
Low	- No indicators of active bed or bank erosion

Flood Hazard

High	- Flooded houses, outbuildings, or arterial roadways
Medium	- Minor roadways flooded, building surrounded but not flooded
Low	- Flooding confined to agricultural land or private drives

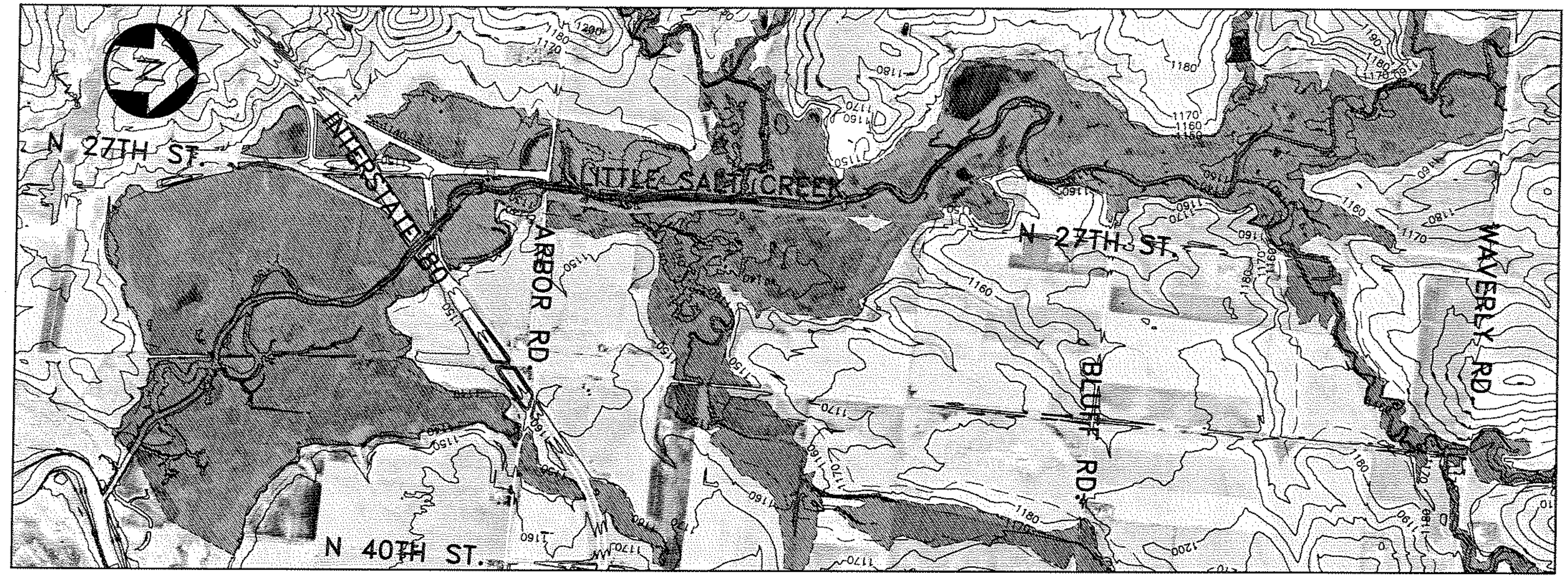
Infrastructure

High	- Exposed or eminently threatened utilities or roadbed
Medium	- Utilities or roadbed present but not eminently threatened
Low	- No utilities or roadbed present

Water Quality

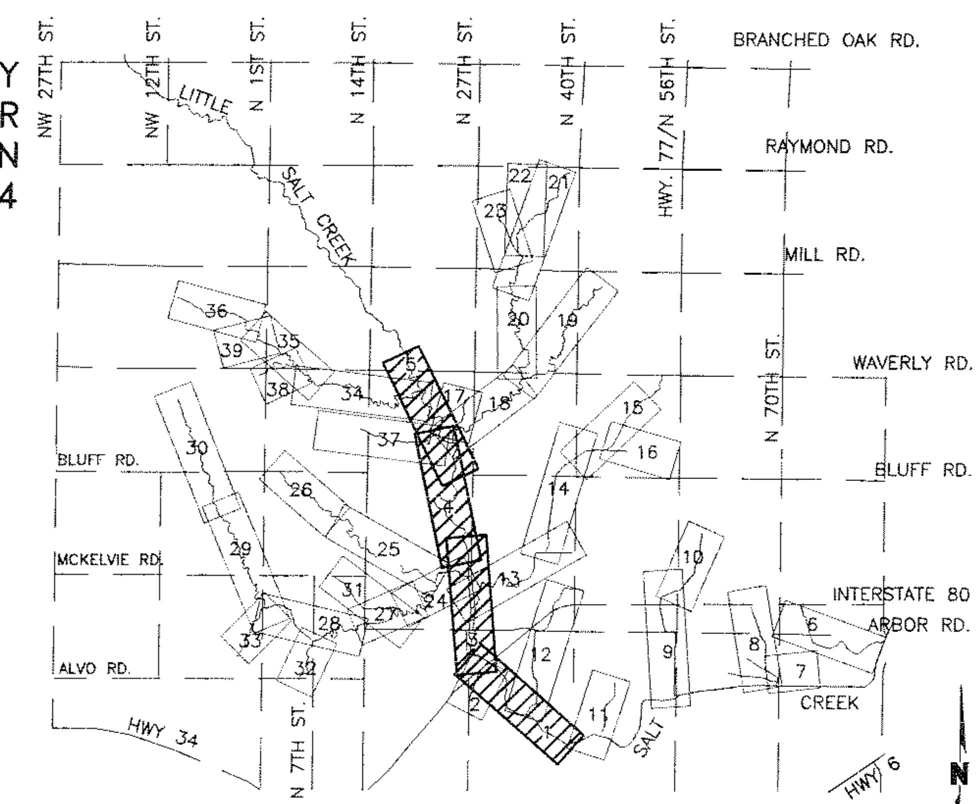
High	- Potential point source pollutant within the floodplain limits
Medium	- Potential non-point source activities without riparian buffer zone

Low	- Potential non-point source activities with 30-ft minimum width riparian buffer zone



LOCATION OF ENVIRONMENTALLY SENSITIVE WETLAND AND WATER AREAS ARE SHOWN ON FIGURES I-3 & I-4

100-YEAR
100-YEAR LITTLE SALT CREEK FIS



LOCATOR MAP

OLSSON ASSOCIATES 1111 Lincoln Mall Lincoln, NE 68508 1-402-474-6311	Lincoln, Nebraska	Plan View of Lower Little Salt Creek Mainstem Interim Stormwater Hydrology and Hydraulics Report for Lower Little Salt Creek Watershed	FIGURE: I-12A

Stream Segment Evaluation

Lower Little Salt Creek (Stream Segments 1 through 5)

Stream segments 1 through 5 comprise the main stem of Lower Little Salt Creek. Segment 3 begins upstream of the Interstate 80 off-ramp and extends parallel to North 27th Street to the Arbor Lake wetlands. Arbor Road and a private low-water driveway cross the channel. The United States Geologic Survey maintains a stream gauge at the Arbor Road bridge. The Arbor Lake wetlands are located adjacent to the channel. The tributaries

Reach Stability

The lower portion of the mainstem is deeply incised, has been realigned and shows signs of ongoing active streambed and bank erosion. The predominant factor causing this erosion is head cutting action that is proceeding upstream from Salt Creek. Three sites were evaluated and sampled using EPA Rapid Bioassessment Protocol to determine instream habitat and conditions for the macroinvertebrate community to establish existing conditions of Little Salt Creek. The upstream most site was near the Northwest 12th Street stream crossing. The site had woody debris in the channel, which provides good habitat for turtles, fish, and macroinvertebrates. Pools followed by a narrow channel and an upland bar provides good channel variability at this location. The next station was at the Waverly Road stream crossing. The channel regime and flow pattern results from the relatively steep channel slope at this location. Riprap under the bridge provides habitat for macroinvertebrates, the banks are vegetated with grasses, and head cutting has exposed the salt hardpan approximately 200 ft downstream of the site. The third site is downstream of Arbor Road. This site has extreme channelization and an abundance of sediment. There is very little vegetative cover in the channel other than filamentous algae.

Flood Hazard Potential

Commodity crops, pasture, and wetlands along the channel are subject to flooding. No buildings appear to be within the limits of the 100-year floodplain.

Threats to Infrastructure

There is no immediate threat apparent to overhead or buried utilities in the road ROW. The roadway crossings in this basin are listed below (see the hydraulics section for more information on overtopping frequency).

Stream Segment	Road Crossing	Meets DCM Criteria?
1	Interstate 80	Yes
1	Interstate 80 off-ramp	Yes
3	Arbor Road	Yes

Roadways subject to frequent overtopping require more frequent maintenance.

Land Use and Ownership

The land around these stream segments is privately held except for the Arbor Lake wetlands, which are owned by the City of Lincoln and managed by the Nebraska Game and Parks Commission, and the Whitehead Saline wetlands, which are owned and managed by the LPSNRD. The land use is commercial south of Interstate 80, and agricultural north of the Interstate with an industrial development currently in progress southwest of the intersection of North 27th Street and Arbor Road. The agricultural land use area is not projected for further development by the LLCCP.

Multi-Purpose Use Potential

Due to the presence of the potential Salt Creek Tiger Beetle habitat along Little Salt Creek, some additional management practices for land use will likely be developed. Based on the Mayor's Salt Creek Tiger Beetle Cabinet Report and other subsequent studies, it is likely that buffer zones will be created or maintained to enhance protection of the species. These areas may be used as protected habitat areas or ecological study areas as well as various other appropriate uses. Preservation of the existing floodplain storage volume would help mitigate the impact of projected development. Much of the area along the channel has saline soils and historically, most of the area not in wetlands has been used for pasture.

Water Quality

Runoff from adjacent and upstream crop land is the dominant characteristic affecting surface water quality.

Saline Wetlands

Runoff into saline wetlands is thought to cause dilution of the salinity level in the wetlands. It is thought that groundwater dissolves chlorides present in the underlying sandstone as it is forced towards the surface. Incision of the channel has reduced the amount of salt-impregnated ground water upwelling into the wetlands where it evaporates leaving behind salt flats with an encrusted mantel of soil. The ground water is, instead, surfacing along the channel where it is confined to a much smaller area.